Compressed Air Magazine

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Compressed Air Magazine

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EDITORIAL CONTENTS

Brewing Budweiser Beer—C. H. Vivian 5018
TVA Today—Allen S. Park 5024
1—General Progress
2—River Development
3—Dam Program
Unusual Equipment Serves Tunnelers—A. M. Hoffmann 5036
Compressors Drive Pumps 60 Miles Away—Elton Sterrett 5038
Editorials—Jobs for Graduates—Measuring Noise—Lower Electricity Rates 5039
Lifter for Sheet Material 5040
New Spray Prevents Offsetting in Printing 5040
Pneumatic Clamps Hold Work on Huge Planing Machine 5040
Industrial Notes 5041

ADVERTISING INDEX

Air Maze Corporation 27
Allis-Chalmers Manufacturing Company 23
American Air Filter Company, Inc. 8
American Brass Company, The 22
Austin-Western Road Machinery Co., The 16
Bucyrus-Erie Company ..... Inside Back Cover
Combustion Engineering Co., Inc. 19
Compressed Air Magazine Co. 27
Coppus Engineering Corp., The 29
Dayton Rubber Mfg. Co., The ..... Insert Between 21-22
Direct Separator Co., Inc., The 28
General Electric 24
Goodrich Company, The B. F. 12-13
Greene, Tweed & Co., ... 28
Hercules Powder Company, Inc. 20
Hills-McCanna Co. 29
Houghton & Co., E. F. 3
Ingersoll-Rand Company 7, 10, 17, 26
Jarecki Manufacturing Co. 29
New Jersey Meter Co. 28
Norton Company 14
SKF Steels, Inc. 21
Socony-Vacuum Oil Co., Inc. ..... Insert Between 10-11
Staynew Filter Corp. 15
Texas Company, The 4-5
Timken Roller Bearing Co., The 25
Torrington Mfg. Co., Inc., The 29
United States Rubber Products, Inc. 9
Vogt Machine Co., Inc., Henry 11
Waukesha Motor Co. 6
Westinghouse Electric & Mfg., Co. 18

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Brewing Budweiser Beer

C. H. Vivian

AT THE peak of the preprohibition era there were 1,472 breweries in the United States. Now there are approximately 750. The record high year for beer production was 1914, when 66,000,000 barrels were brewed. At the present time the annual brew is around 42,000,000 barrels. Thus the industry is currently operating at about 63 per cent of its maximum level and with about half of the former number of plants. If the intervening growth in population is considered, the contrast is even more marked, the annual output being 11½ gallons per capita as against 20 gallons in 1914.

There are several reasons why the country consumes only two-thirds as much beer as it once did. Chief among them is taxes. In 1914 Uncle Sam collected $1 on every barrel of beer: today he collects $5. In addition, many states impose taxes. These range as high as $4.65 a barrel, and average $1 a barrel. As a result, even

RACKING

The machines at the left fill the barrels without causing the beer to foam. A barrel holds 31½ gallons. Budweiser is also packaged in half-barrels and quarter barrels. Anheuser-Busch's investment in cooperage is around $2,500,000. Barrels returned to the brewery are soaked twelve hours to tighten joints. Bungs are next drilled out and the barrels washed inside and out. The interior pitch coating is then melted out and a fresh application made. After another washing and careful inspection the barrel is ready for refilling.

The picture above shows the brewery from the air. It makes up only a relatively small portion of the Anheuser-Busch industries. In the foreground is the bottling plant, a $6,000,000 structure that contains 25 acres of floor space. Eleven railroad tracks enter its basement and there is interior trackage to accommodate 110 freight cars. Just above the upper right-hand corner of this building is the office, which was formerly a school attended by the father of the present Busch brothers. Largely for sentimental reasons, he acquired it and refitted it for executive offices. It is still so used. Just above it is the malt house, and across the street to the left are the brew house, power house, and fermenting cellars.

1,000,000 BOTTLES OF BEER A DAY

. . or 65 carloads every eight hours. That is the capacity of the bottling equipment shown here. It is on the sixth floor of the bottling plant. There are eighteen units in this line, each consisting of a washer, bottler, capper, pasteurizer, and labeler. These respective operations are performed from right to left. Cases of empty bottles are unloaded from cars in the basement on to conveyors which transport them to the uppermost part of the building. There they feed on to six spiral conveyors each of which serves three bottling units. The cases descend by gravity to the rear of the washers, where the bottles are taken from them by hand and placed in a revolving drum that carries them into the machine. The emptied cases continue down to a lower floor for inspection and repairs.

The bottles are washed with a hot caustic solution for 25 minutes, and then receive four internal and external scourings with brushes. The filling and capping machines will handle 120 bottles per minute. The filled bottles enter a pasteurizer, where they spend one hour in a temperature that is maintained at approximately 148°F. They emerge and travel to a machine that applies two labels to each bottle. Finally, they are packed by hand into cases which, having been repaired and elevated to a point overhead, move down spiral conveyors to the packers in an endless line. The filled cases go by gravity back to the basement for loading into cars for shipment.

As sunlight is harmful to beer, the skylights which illuminate this vast room are placed so that they admit only north light. Brown bottles are used exclusively.

though the brewery charges no more, or even less, per barrel than it did in 1914, the public gets less for its money and buys less.

Most breweries sell their beer within a relatively small area. For example, there were at one time more than 100 breweries in the City of Greater New York. From them came a goodly proportion of the 14,000,000 barrels of beer which New York State sometimes consumed in a year, but probably not more than three or four of their brands were known as far away as Philadelphia, and many of them drew trade from only their immediate neighborhoods. Of all the nearly 1,500 beers on the market, but a small number was procurable in the country at large. Among the select few was Budweiser. Times have not changed much in this respect, for with legal beer back again in most parts of the United States, Budweiser once more is known and sold not only nationally but internationally. In fact, it is said to be one of three beers brewed in America that can be obtained in every country where beer is consumed. Budweiser has the largest sale in the world and, it follows logically, is made in one of the world's largest breweries—that of Anheuser-Busch, Inc., in St. Louis, Mo. In 1914 there were brewed well over 1,600,000 barrels of Budweiser; in 1934 more than 1,100,000. In both years, however, Budweiser constituted about 2½ per cent of the beer made in this country—about one barrel in every 40.

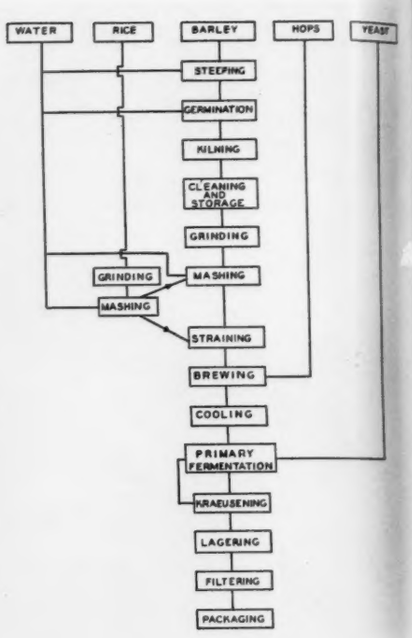
Debates are frequent among beer drinkers as to the relative merits of present and past beer. So far as the visitor to the Anheuser-Busch brewery can learn, it is the sense of taste that has changed and not the beverage. Budweiser beer is brewed just as it always was. The aging period is the same as of old.

The Anheuser-Busch industrial development, of which the brewery is a part, is one of the greatest in the country. Certainly, its like cannot be found in the heart of any other of our large cities. It is on the same but enlarged site as the original brewery that started operating in 1857 and that has been brewing beer or near-beer without a break since then. In addition to the brewery, there are now centered there the nation's second-largest yeast plant, a large corn-products refinery, and a truck-body and refrigerator-cabinet plant. Combined, they occupy 110 buildings grouped on 71 city blocks.

In this article we shall be concerned only with the brewery. It is of rather imposing size in itself, as may well be judged from the fact that it can turn out 2,000,000 barrels of beer a year. Into a year's brew go 67,000,000 pounds (1,400,000 bushels) of barley, 19,000,000 pounds of rice, and 850,000 pounds of hops. Despite its great

BREWING

A general view within the brew house where malt and rice mashes are prepared, united, and the wort is extracted from them and brewed. The materials move progressively downward during these operations. Each of the copper brew kettles along the sides of the two lower floors is 18 feet high and holds 450 barrels of wort. As this is boiled by heat applied through steam jackets, quantities of hops are added from time to time from the containers resting on the first floor. Imported hops from Bohemia and Czechoslovakia currently cost about $1.25 a pound. Domestic hops, raised principally in New York State, sell for around half that figure. The two large chandeliers represent growing hop vines. Suspended from them is the well-known Anheuser-Busch emblem and trade mark. Six of these huge fixtures were imported from Germany a number of years ago.



FLOW SHEET

This diagram shows the principal steps in the making of Budweiser beer. Anheuser-Busch is one of the few American breweries that prepare their own malt. This gives it control of the complete brewing process and, accordingly, of the product. One of the greatest problems of brewers is to get dispensers to observe the same scrupulous care and cleanliness in serving beer that they do in preparing it. Principal "dont's" for bottled beer are: Don't cool below 35°F.; don't expose to light; don't open until just before serving; don't use glasses unless they are immaculately clean.

proportions, Anheuser-Busch, Inc., has remained essentially a family enterprise. Its principal executive officers are Adolphus Busch III and August A. Busch, Jr., great-grandsons of the founder, Eberhard Anheuser.

Budweiser beer is made by a formula that was formerly used by the Budweis monks in Bohemia and that was brought to this country many years ago. While modern brewing is in the main a chemical process, with the various steps subject to laboratory control, nevertheless, human skill, judgment, and experience are still vital factors. Two individuals largely determine the character of Budweiser beer and keep it uniform. They are the maltster and the brewer.

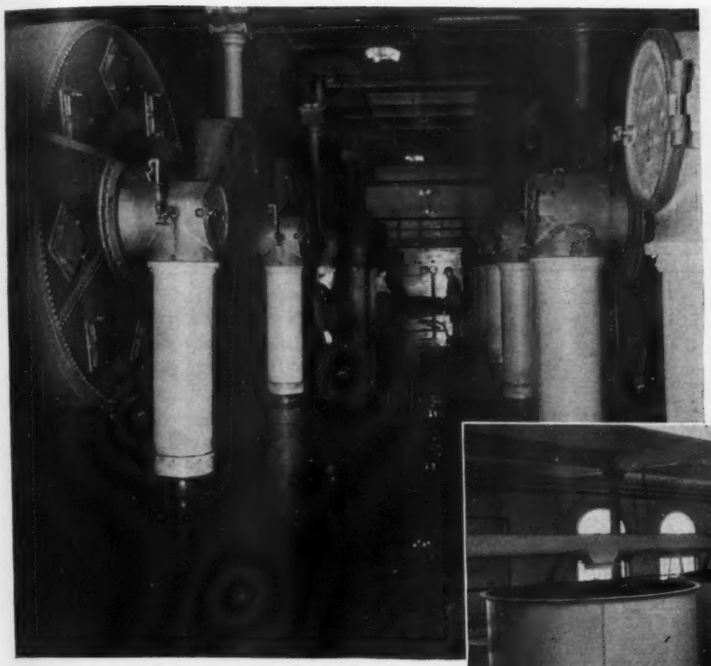
The *American Handy-Book of the Brewing, Malting, and Auxiliary Trades* defines beer as "a beverage produced by alcoholic fermentation from a hopped infusion, either of malted cereals, preferably malted barley, exclusively, or with an addition of unmalted or prepared cereals." The materials that enter into Budweiser are barley, rice, hops, yeast, and water. The process by which beer is made can be divided into four parts, namely, malting, brewing, fermenting and aging (lagering), and packaging.

Malting prepares the cereals for brewing. It consists essentially of artificially causing the grain to sprout, as it would if it were planted, and of checking its growth at the exact stage where it is in the most usable form. The materials that give beer its substance are found only in malted grain. Palatableness, foam stability (head), taste, aroma, and color are derived largely from the malt. Barley is accepted as the basic malt cereal, as it possesses the following favorable attributes: (a) a large starch content; (b) a husk that forms an excellent filtering bed; (c) in the malting process it generates the enzymes which are essential to brewing. These enzymes are principally diastase and peptase. A kernel of barley consists of husk, germ, and endosperm. Stored in the endosperm is the nourishment for the germ during the sprouting season. This nourishment is largely starch, albuminoids, and small amounts of mineral matter. The enzyme diastase has the power to transform the malt starches into malt sugars: the peptase makes the albumen soluble and, therefore, usable.

All but a few breweries in the United States buy their malt from concerns that specialize in its preparation. Anheuser-Busch is one of the exceptions. By doing its own malting, it can control the entire beer-making process and, consequently, can individualize the product to the fullest extent. Malting is under the complete control of the maltster. Where he leaves off, the brewer begins.

Malting may be divided into the four operations of steeping, germinating, kilning, and cleaning and storing. Steeping consists of submerging the barley in water for a length of time which varies anywhere from 24 to 64 hours, depending upon the grain. Barley is graded according to the size of the kernels into Nos. 1, 2, and 3. Only the select grades are used for Budweiser beer. Steeping the barley arouses its vitality to such a degree that it is prepared for germination. During that operation the grain absorbs approximately 50 per cent of its own weight in water.

The process of germination causes the barley to sprout artificially and brings it to the desired stage, as determined by the



MALTING

All malting of barley is done in the cool-weather season from October 1 to June 10. Storage capacity (tile-and-steel silos) is provided for 1,600,000 bushels of barley. In 1934, a total of 1,400,000 bushels was malted. The malting equipment, housed in a separate building, can handle 6,000 bushels a day. The choicest barley normally comes from the Dakotas, Iowa, Wisconsin, and Minnesota. The first step in malting is to steep the grain for up to three days in the tanks shown below. An air pipe extends to the bottom of each tank, and the contents are thoroughly aerated and agitated at regular intervals. On the fourth day the barley is placed in the pneumatic drums at the left. They make one revolution an hour. A current of cool, moist air, which duplicates the natural atmosphere of the spring growing season, is continually circulated through the grain and induces sprouting or germination. After the growth has progressed to the desired point it is checked by drying the barley in flat-bed kilns where warm air is drawn through it. It spends a day or more in each of two kilns.

maltster. It is carried on in large floor compartments or in pneumatic drums of special design. In either case a current of conditioned air is passed through them. This air is controlled as to humidity and temperature, the latter being maintained at degrees determined by the maltster. During the germinating period the starch content is modified as a result of the action of the enzyme cytase upon the cellulose partitions between the starch granules, which action changes the woody structure of the grain into one of a tender, friable nature. At the same time sufficient diastase is generated to convert to sugar all the raw starches contained in the malt plus an equal amount, by weight, of the starches contained in the rice, which will be brought together with the malt during the subsequent brewing process. Peptase, valuable, as already noted, for converting albumen into soluble nitrogenous substances, is likewise formed.

The next step is kilning. The germinated barley or "green malt" is placed on extensive, perforated false-bottom metal floors through which hot air is passed to reduce the moisture content. This imparts the desired aroma and flavor to the malt and renders it stable for storage. The maltster controls the drying process within definite limits to produce, as he may desire, a low-dried, intermediate-dried, or high-dried malt—a range which extends from a light malt at one extreme to a dark malt at the other. Whether the resulting beer is light or dark depends primarily upon the manner in which the malt is dried. As the diastase content is extremely sensitive to change in the presence of moisture at high temperatures, the maltster exercises much care to make sure that he does not destroy or impair the value of this ingredient. The air by which the drying is effected is heated, directly or indirectly, by furnaces fired with coke, coal, or gas. Thus processed, the malt is ready for cleaning, which involves the removal of the rootlets or sprouts. This is accomplished in special machines. The cleansed malt is stored for a post-malting period.

Brewing, like malting, consists of four operations: grinding the grains, mashing, straining, and kettle treatment. In the first of these, barley malt and rice are ground in mills designed to prepare them for mashing. The ultimate mash is a mixture of malt and rice mashes, each of which is produced separately. In making the former, malt is placed in a tank with a definite quantity of water and agitated to assure a homogeneous mixture and to start the action of the enzyme peptase upon the contained proteins. During this operation the mash is heated to a temperature designated by the brewer.

In preparing the rice mash, water is first introduced into a cooker. A predetermined amount of malt mash from the malt-mash tanks is next added, and then the rice. This mixture is heated slowly to boiling by means of a steam jacket, and is held there for a definite period. During this time the rice is gelatinized preparatory to the conversion of its contained starches into sugars (some conversion takes place in the cooker).

The malt mash, at a predetermined temperature, and the rice mash, at boiling temperature, are introduced into a strainer tank in such amounts as the brewer may determine in order to obtain a final desired temperature, which depends upon the character of the beer that is to be made. The straining tank is a vessel having a false, perforated bottom which serves to filter the soluble matter from the insolubles. It is during this stage of the process that the complete conversion of the starch content of the grain into maltose sugar and into the intermediate malto-dextrose compounds takes place. The residue in the tank is sparged—that is, sprinkled with hot water to aid in removing all the soluble contents. The liquid extract that is drained off is known as wort and is pumped to large copper kettles, each of 450 barrels capacity.

By means of heat applied through a steam jacket, the wort is boiled vigorously in the kettle for four to six hours. At intervals are added charges of hops, consisting of flowers from the female hop plant. Either domestic or imported hops, or a blend of both, are used in the proportion designated by the brewer. At the base of the cone of leaves which makes up the hop flower are tiny grains which compose the lupulin. In it are stored the constituents that are valuable for beer making. These are: hop oil, which carries the aroma; hop resin, which imparts the bitter taste to beer and which, because of its germicidal properties, contributes to its stability; and hop tannin, which causes certain albuminoids to be separated from the wort when it is boiled. The percolating action which takes place in the kettle serves to precipitate objectionable protein compounds and

AMMONIA COMPRESSORS

The refrigeration equipment in the Anheuser-Busch plant has a capacity to produce a volume of cold that would freeze sufficient ice to supply a city with a population of more than 1,000,000. Noteworthy among the eight ammonia compressors is the Class PRE-4 at the top of this picture. It has a compression cylinder at each of the four corners of the frame and is driven by a centrally placed 1,500-hp. synchronous motor. Its rated capacity is 900 tons of refrigeration when handling gas at 15 pounds suction pressure and 185 pounds discharge pressure. Below it is a section of a 2-cylinder Class PRE-2, 450-ton-capacity machine that has run nearly 10,000 hours without having required any cylinder or valve repairs. It was the first compressor to be equipped with channel valves.

to impart the desired hop flavor to the wort. At the expiration of the boiling period the wort and hops are withdrawn into a container known as a hop-jack. This is a vessel with perforated sides and bottom and equipped with an agitator. The hop-flavored wort which is extracted is run over a cooler to the fermenting and stock cellars to undergo fermentation and aging. The spent hops are retained in the hop-jack, from which they are removed as required.

The wort is cooled by passing it over a cooler, consisting of a series of tubes arranged in vertical tiers. The wort is allowed to run down over the tubes and is cooled by a liquid which is circulated through them. In this case water is pumped through the upper tube sections and ammonia is expanded in the lower ones. During the cooling operation, which is conducted in an air-conditioned compartment, additional objectionable proteins are precipitated.

The cooled wort goes to a large air-conditioned "starting" cellar, so named because it is there that fermentation starts. Measured quantities of yeast are added and, after standing for a prescribed period, the wort is discharged into the fermenters where it undergoes primary fermentation for a period of twelve to fourteen days. During fermentation the sugar content is split up into approximately equal parts of alcohol and carbon-dioxide gas, the disintegration resulting from the chemical activity of enzymes in the yeast. The sugars present in beer wort are maltose, saccharose, malto-dextrin, dextrose, and levulose. Only the two last mentioned are directly fermentable and the others must be converted into them before they can be split up. Conversion is effected by the enzymes invertase and maltase in the yeast. Brewers consider this primary fermenting period one of the most vital in the entire process of brewing. Any variation in the temperature will alter the character of the brew. Meticulous care is consequently taken to maintain uniform conditions. The partially fermented wort or beer is cooled to slightly above the freezing point and stored in large wood or glass-lined steel tanks or vats.

The second stage of fermentation begins with the introduction of chips or strips of beechwood that have been suitably prepared for the purpose. At the same time there is added what is known as kraeusen—wort that has been partly fermented. At that stage it is still undergoing the active generation of carbon dioxide in connection with the breaking up of the sugar content. By adding this 15-to-25-per-cent-fermented beer to the 75-to-85-per-cent-fermented beer, the desired degree of carbonation is obtained naturally. As a constant counter pressure is maintained on the wort, the gas is entrained in it. Beer which is carbonated in this way is said to be kraeusened, and is distinguished from that which is carbonated by introducing gas from an outside source. This period of processing, which is known variously as secondary, kraeusen, or as chip fermentation, is continued for from six to eight weeks. Besides carbonating and clarifying the beer, it assures a final product that will retain the natural bouquets, esters, and aromatic extracts which are derived from the parent ingredients.

The finished beer is pumped to double-piped coolers and chilled to a temperature slightly above freezing. It is then stored in tanks or vats. As a final treatment before placing in containers for marketing, it is passed through pulp-type filters to remove suspended yeast. It emerges a clear, sparkling, amber-colored beverage.

In reading the foregoing account it has perhaps been noticed that from the time wort is produced until it becomes finished beer the liquid is maintained at low temperatures. In view of the fact that the brewery under consideration is one of the largest in existence, and that some of the allied industries also require subnormal temperatures, it is not surprising to find that the refrigerating plant at Anheuser-Busch is one of the biggest industrial installations of its kind in the world. It includes eight machines with an aggregate capacity of 3,340 tons of refrigeration every 24 hours. This amount would freeze 2,230 tons of ice a day, which is sufficient to supply the normal requirements of a city of 1,085,000 persons, or of St. Louis and Denver combined.

The individual capacities of the eight units, expressed in tons of refrigeration, are: 380, 230, 230, 250, 300, 450, 600, and 900. The three first listed are steam-driven, single-cylinder, vertical ammonia compressors. The 600-ton machine is of the steam-jet, water-vapor type and was provided to supply chilled water for the yeast plant. The other four machines are electrically driven, 2-stage, horizontal ammonia compressors. The three steam units are the oldest, having been in service 44, 35, and 34 years, respectively. The first machine, when installed in 1892, was the largest ammonia compressor in existence. As time passed, bigger units were naturally built; but in 1935 the distinction formerly held by Anheuser-Busch was regained, for the 900-ton machine which was put up last year is, so far as available records show, the world's largest electric-driven ammonia compressor. It will be described later.

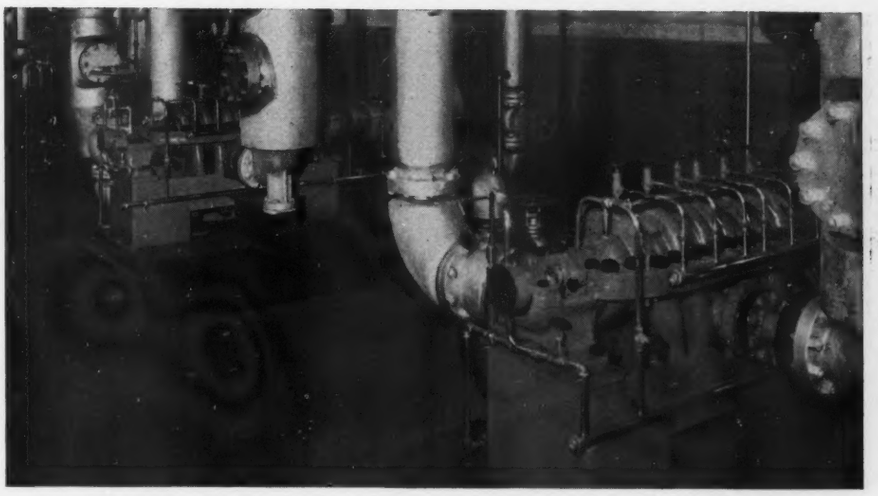
The capacities of the various ammonia compressors just given are based on a suction or intake pressure of 15 pounds to the square inch and on a discharge pressure of 185 pounds, these being the operating conditions at the plant. There is a demand for some refrigeration 24 hours a day and 365 days a year, and there is always at least one machine in operation. At the height of the hot-weather season it is sometimes necessary to run all the units. In the cooler periods, when the load tapers off, it is customary to run only the steam machines, in conformity with general power-plant practices.

The ammonia piping system covers vir-

tually the entire 71-block plant area, much of it being underground. It is estimated that there are 300,000 pounds of ammonia in circulation. There are eight ammonia receivers, each 30 inches in diameter and 18 feet high, with an aggregate capacity of 37,440 pounds. While the greater proportion of the refrigeration is needed in the brewery, some of it is also required in the yeast plant, in the corn-products refinery, and for air conditioning two office buildings. Its largest single service in the brewery is for cooling stock houses and cellars. The older installations consist of brine pipes along the ceilings, or of ammonia expansion coils: the new ones, including that just placed in an improved fermenting cellar, are arranged for blowing air across ammonia coils.

There is an ice plant with a capacity of 180 tons a day. The product is used for icing cars of draft beer shipped from the brewery, and the surplus is sold to local dealers. The output is very small in winter when, instead of icing the cars, it is not unusual to pack the barrels in hay to guard against freezing, particularly in the case of shipments going long distances to colder sections of the country. In preprohibition days, when only the larger cities had ice-making facilities, Anheuser-Busch maintained a 1,000-ton plant and sent the product considerable distances for re-icing cars *en route* and for sale to distributors. But this market gradually dwindled until, with the production of near-beer during prohibition, the plant's usefulness came to an end. Near-beer was not sold in barrels and did not require icing for shipment.

Meanwhile, the general refrigerating plant had been taking care of the cooling requirements of the brewery and of the growing yeast plant and corn-products refinery. With the rebirth of the beer industry in 1933, the demand for refrigeration increased, and it became apparent that the plant's capacity would have to be enlarged. In doing this it was decided to discontinue the services of some of the older machines and to replace them with larger, modern ones. One of the new machines bought at that time was the 450-ton unit. It is an Ingersoll-Rand Class PRE, horizontal, duplex, 2-stage compressor having cylinders 24½ and 17 inches in diameter and a stroke of 24 inches. It is driven by a Westinghouse 800-hp. synchronous motor. This machine was put in service on June 4, 1934, and was inspected in March, 1935, after 5,775 hours of operation, at which time the cylinders and valves were found to be in good condition. Since then it has run 3,708 additional hours, or a total of 9,483 hours, without any repairs to either cylinders or valves. Attention is directed to this record because this was the first compressor to be equipped with valves of the new and improved channel type. These valves are now standard on most of the larger sizes of Ingersoll-Rand air and gas compressors; but when this machine was built they were just being introduced.



BOILER-FEED PUMPS

Anheuser-Busch generates its own power with coal from its own mines, and furnishes great volumes of steam for processing work. Four modern boilers have a combined heating surface of more than 40,000 square feet. Boiler-feed water is supplied by the four Cameron centrifugal pumps shown here. The two in the foreground are 360-hp., 6-stage, turbine-driven units. In the background are two 350-hp., 4-stage units, one motor driven and the other turbine driven.

In pursuance of its expansion and modernization program, Anheuser-Busch last year purchased the 900-ton ammonia compressor previously referred to as the largest electric-driven unit of that type ever constructed. This is likewise an Ingersoll-Rand Class PRE machine, but it differs from the first one. Instead of two cylinders, it has four—one at each end of the two frames. The driving motor, a Westinghouse 1,500-hp., synchronous type, is located centrally between the frames. This 4-corner design has been applied for several years to some of the large Ingersoll-Rand air and gas compressors, but this is the first time it has been employed in connection with an ammonia compressor. The unit is also provided with channel valves. It was placed in service on June 15, 1935, and has operated 2,953 hours without having required any repairs.

Following its compression, the ammonia gas is condensed in twelve shell-and-tube-type coolers which, combined, condense 1,000 pounds of ammonia per minute when using cooling water at 85°F. The water is circulated through the coolers and over a cooling tower by twelve Cameron Type NFV centrifugal pumps. These have a total capacity of 40,000,000 gallons of water per day, or enough to supply a city of 300,000 population. The cooling tower, which really is made up of thirteen towers, is one of the largest installations of its kind in existence.

Anheuser-Busch generates its own power. It has its own water-supply system—a pumping plant on the shore of the nearby Mississippi River with a capacity of 15,000,000 gallons daily. This water is used for general plant purposes, but the St. Louis city water is employed in making the beer. The latter is one of the purest municipal waters in the country, and is very satisfactory for brewing without preliminary treatment.

The power plant contains four Springfield boilers which have been installed in the past six years to replace two batteries of older boilers numbering 25 units. Three of the present boilers have 10,760 square feet of heating surface, and the fourth has 9,130 square feet. They burn pulverized coal which is prepared in Hardinge ball mills. Each of the burners of the larger boilers has a feeding capacity of 9,000 pounds of coal per hour. The power plant is unusual for an industrial installation in that it has facilities for generating steam at 500 pounds pressure and for furnishing quantities of it at 140 pounds, 35 pounds, and 5 pounds to meet processing needs.

Most of the power is generated as 2,300-volt, 3-phase, 60-cycle, alternating current, and is delivered at either 2,300 or 440 volts. As some departments still have 230-volt direct-current equipment, the necessary power is supplied by converting 2,300-volt current by means of four 500-kw. motor-generator sets. Additional 230-volt current is developed by two 500-kw. direct-current generators driven by vertical steam engines. The 2,300-volt current is produced by three turbo-generators. Two of these are 3,750-kva., Allis-Chalmers units which are arranged for extracting steam at 140 pounds pressure and for exhausting at 5 pounds pressure. The third machine is a 5,000-kva., General Electric unit arranged for extracting steam at 35 pounds pressure. It is served by an Ingersoll-Rand surface condenser. Normally, the larger turbine and one of the smaller ones are operated to supply process steam at the three required pressures. On Sundays, when the demand for 140-pound steam is small, it is drawn from a desuperheater, and only the 5,000-kva. generator is in service.

ARTIST'S CONCEPTION OF WHEELER DAM

This 6,335-foot wall of concrete spans the Tennessee River at the head of Wilson Lake. At the near end is a part of the power house in which two 45,000-hp. turbines are now being set up and in which are positions and intake works for an ultimate possible installation of 360,000 hp. Wheeler Dam will be completed during the coming summer. Its cost, including the reservoir site, will be approximately $34,000,000.

1- General Progress

Allen S. Park

TWENTY months have passed since we outlined the purpose of the Tennessee Valley Authority and described the construction operations that were then underway. At that time a general plan had been formulated for the systematic development of the Tennessee River Basin and a good start had been made on Norris and Wheeler dams. In the interim, the plan has assumed more definite form, and much progress has been made towards putting it into effect. The ramified but correlated activities of the program have been broadened in scope and extended in area. They now cover virtually every phase of development provided for in the scheme and reach into almost every part of the 40,000-square-mile territory that will eventually feel their influence. Although TVA will not be three years old until next month, the pattern is beginning to show itself in the structure it is weaving.

To clarify our description of the continually changing picture as it exists at present, we shall briefly review the objectives of the plan. The broad aspiration of TVA is to bring about a new economic and social order in a region about the size of England and populated by approximately 2,000,000 persons. This sounds abstract and involved, but when the scheme is resolved into its component parts it is found to consist of a grouping of concrete, simple elements.

The two major aims are: First, to restore to its former productiveness a vast expanse of land which, because of past abuses, has been transformed from an asset into a liability; and, second, to control the flow of the Tennessee River so as to prevent floods and to provide a 9-foot, all-year-round navigation channel from its confluence with the Ohio River at Paducah, Ky., to Knoxville, Tenn., a distance of 650 miles. The method of accomplishing the second purpose is by erecting a chain of dams on the Tennessee and its principal tributaries. These dams will give rise to potential power in the form of falling water, and this will be used to generate electric current. The power will be essentially a by-product. Inasmuch as its sale will pay a part or perhaps all of the cost of the entire development, it is a very important phase of the scheme, but it is an incidental benefit and not one of the primary reasons for the undertaking.

Rehabilitation of the land involves several steps. First, a stop must be put to erosion which has for many years been laying it waste. This is being done by terracing and by building retaining structures. Next, the soil must be fixed by planting trees and suitable crops, such as grasses and legumes. Finally, the impoverished ground must be rendered fruitful again by the application of fertilizers. It so happens that inexpensive power can be advantageously applied to the manufacture of fertilizer, hence the river, to the extent that the hydro-electric energy is so used, will be contributing to its own development. Furthermore, if the dams are effectively to prevent floods and to maintain navigable channels for years to come, it is essential that their reservoirs be not clogged with silt. The fixing of the soil in the drainage area will insure against this. Thus we see that some of the aspects of the general scheme dovetail nicely in the furtherance of the unified whole.

Manifestly, it will be impossible for

people to support themselves on the land until some of its productiveness can be restored. Many of them will, accordingly, be given part-time employment in forestry work or, later on, in small industrial plants of such types as the region can support. Meanwhile, they will be taught to make more effective use of the land by planting crops that are suitable to it and by not planting crops such as corn, which accelerates erosion of sloping ground.

Being visible and spectacular features of the TVA program, the dams naturally command the major share of public attention, but some of the lesser-known activities are equally interesting. The production of fertilizers is one of them. It will be recalled that the wartime development at Muscle Shoals was turned over to the TVA by the terms of the legislation that created it. It consisted of Wilson Dam and power house and of two plants that had been built for the manufacture of ammonium nitrate, a substance essential to the making of explosives. The first plant was obsolete by the time it was finished, just before the armistice was signed in 1918. The second was successful, but as the war had terminated it was never operated save for a trial run, and lay idle until the TVA research chemists appeared on the scene.

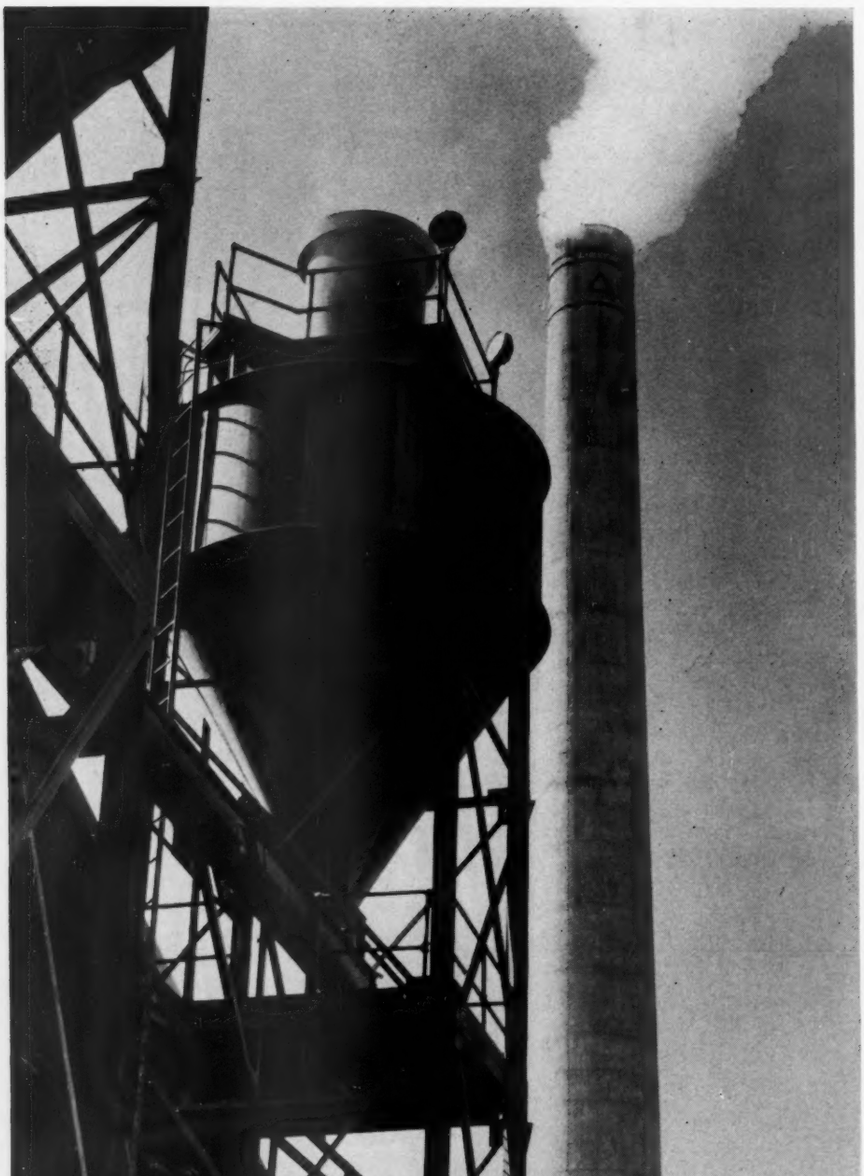
During the intervening years Muscle Shoals was the subject of many heated debates in Congress. It was clearly the belief of the legislators that this vast public investment should be put to use for the peacetime development of fertilizers, but they could never agree upon a specific plan for effecting this. It was definitely written into the TVA act, however, and no time was lost after Muscle Shoals was turned over to the Authority on July 1, 1933, in starting investigations. Both plants had been designed for the manufacture of nitrates by the fixation of atmospheric nitrogen. One of them was known to be of no value, and a little study revealed that the second one also was not commercially operable as it stood. In any event, the TVA chemists had determined that present conditions in the Tennessee Valley call for a phosphatic fertilizer rather than a nitrogenous one. As explained by Dr. A. E. Morgan, chairman of the TVA directors, these conditions are as follows: "The eroded hillsides must be put into grass and other forage crops if the population is to be kept on the land. But in this region grass will not grow without nitrates in the soil, and nitrates cost too much to buy as fertilizer. It is much cheaper to produce nitrates in the soil by planting nitrogen-fixing legumes. Yet these will not thrive until the soil is enriched with phosphates. So we begin where we must."

It was therefore decided to strive for improvements in the production of phosphatic fertilizers, and material progress has been made in that direction. The greater part of the fertilizer now used in the United States is of this character, and most of it is manufactured as a superphosphate containing between 16 and 20 per cent of available plant food. Some "triple superphosphate" with a higher percentage of available plant food has been offered, but it has not been well received by farmers because of its higher price and because of their failure to understand that in point of plant food it is the more economical of the two. Another deterrent to its wider application has been the fact that no economical process for making it has been known. The present method is to treat phosphate-rock dust with sulphuric acid to form phosphoric acid of 45 to 55 per cent strength, and then with that to treat phosphate-rock dust. This yields a gummy product that is difficult to handle and that must be dried and aged before being marketed. In this situation, the TVA chemists sought a better and less expensive process, and as a starting point they conducted experiments to learn how higher-strength phosphoric acid would react on phosphate-rock dust. They found that an acid of 80 per cent strength would give a relatively dry product that required practically no aging.

With low-cost power available from Wilson Dam, it was decided to use an electrical process to smelt phosphate rock for the production of phosphoric acid. A plant of commercial size was built, utilizing two 6,000-kw. electric furnaces that had been installed in Nitrate Plant No. 2. A plant of this size was chosen so that manufacturing costs might be determined and so that sufficient fertilizer could be made adequately to demonstrate it in connection with a large-scale agricultural program. The phosphate rock, which exists in large quantities in the Tennessee Valley, is smelted with coke and silica at a temperature of about 2,750°F. The reduction with coke liberates phosphorus, and the silica combines with calcium in the rock to form calcium silicate. The phosphorus is burned to form phosphorus pentoxide, and is then combined with water to form phosphoric acid of

EROSION CONTROL

These pictures show the same hillside area as it looked on March 7, 1934, and on September 13, 1935. During the interval of eighteen months the denuded slope was covered with vegetation which has effectually stopped washing and which will eventually restore the tract for cultivation of some kind. Stone check dams and brush mulch (above) were first placed, and then black-locust seedlings were planted. These leguminous trees grow fast and have a matted root system that holds the soil in place.



PHOSPHATE PLANT

TVA chemists have developed commercial processes for making superphosphates containing much higher percentages of available plant food than those now being marketed. They are also producing pure phosphorus, which can be shipped to various parts of the country for manufacturing fertilizers.

about 80 per cent strength. When mixed with phosphate-rock dust, this acid produces a superphosphate that contains on an average 43 per cent of available plant food, as compared with 16 to 20 per cent for the superphosphate now being generally marketed. The latest annual report of the TVA, which covers activities for the fiscal year ending June 20, 1935, records that 19,210 tons of the new fertilizer had been manufactured up to that date.

This TVA superphosphate, containing 43 per cent available plant food, is equivalent to a phosphorus concentration of 18.8 per cent. In an effort to increase this percentage, another superphosphate was produced with an available plant-food content of 62 per cent, which is equivalent to a 27.1 per cent phosphorus concentration. The optimum in this respect is, of course, pure phosphorus, and this is now being made in a second plant that was designed for the purpose. It cannot be used as a fertilizer until it is mixed with phosphate rock; but in its highly concentrated form it can be shipped to remote parts of the country for subsequent mixing, thereby saving materially on transportation costs. As the largest phosphate deposits are in the western half of the country, this development may prove helpful to the farmers of the nation at large.

A comprehensive system of experimentation and demonstration is now underway to determine the results that can be obtained with the TVA fertilizer. It differs from most phosphatic fertilizers in that it contains no gypsum, and this may cause it to have a different effect upon the soil. For demonstration purposes, twenty farms are being selected in each of the 100 counties in the valley, making 2,000 in all. These are located in easily accessible sections and are well scattered so that all farmers who may desire to visit them can do so conveniently, thereby giving them great educational value. The fertilizer is provided free of charge, and its use is limited to crops that are effective in the control of erosion, such as grasses, legumes in mat planting, and small grains. The farms are selected by committees in each community, and the committees are selected by soil-conservation associations that have been formed by the farmers thus far in 95 of the 100 counties. In return for the fertilizers received and the assistance given them, the farmers on whose lands the demonstrations are conducted agree to carry out instructions as to the proper procedure and to keep records of crop yields.

The act that created it, charged the TVA with the responsibility of maintaining Nitrate Plant No. 2 in condition for the fixation of atmospheric nitrogen and for the manufacture of explosives as a measure of national defense. This has been done, and it is officially reported that it could, in the event of need, turn out 110,000 tons of ammonium nitrate annually. It is also pointed out that elemental phosphorus, when burned, has the highest total obscuring power of any smoke screen known. The 2-furnace plant now being operated by the TVA can produce 6,000 tons of phosphorus yearly, while any or all of the ten electric furnaces in Nitrate Plant No. 2 likewise could be utilized for making phosphorus. Other products that could be manufactured there are given as calcium carbide, electric steels and certain alloy steels, abrasives, and refractories.

It is generally recognized that large sections of the Tennessee Valley are suitable only for growing trees, and in line with that policy attention is being given to the reforestation of hillsides from which the timber was cut by past generations. As a basis for long-range land-use planning, a preliminary survey of the entire valley has been made, and areas totaling 4,000,000 acres have been designated as suitable for acquisition by the United States Forestry Service. Such acquisition would, of course, remove this land from agricultural use, except such as might be authorized by that agency.

In addition to this long-term program, forest control is being carried on in connection with definite structural features of the project. For example, the land around Norris Lake has been taken over in order to protect the reservoir, and as it is predominantly forest land, a management plan is being applied there with the purpose of developing it while also controlling

it to prevent erosion, trespass, damage, and fire. The aim is to demonstrate that such areas can support a certain number of persons by combining part-time forestry employment and part-time farming. The groundwork has been laid for the establishment there of farm-forest settlements.

Reforestation is linked with erosion control, in which activity the TVA has had the assistance of several thousand CCC workers. During the period covered by the last annual report, 5,383,000 trees were planted on 1,846 acres. Trees are set out only after scouring of the land has been stopped through the erection of appropriate engineering structures. Two forest-tree nurseries have been established, one at Clinton, Tenn., and one at Muscle Shoals, Ala. They will have an ultimate combined capacity of from 40,000,000 to 50,000,000 one-year seedlings annually.

Another TVA activity that is little known is that of ceramics research, for which a laboratory has been set up at Norris, Tenn. It is a definitely established fact that the Tennessee Valley has a large supply of kaolin, a mineral that is essential to the manufacture of fine chinaware. Processes of refining this kaolin are being worked out, and efforts are being made to develop and to demonstrate methods by which it can be used in the making of the whiteware which is now almost exclusively imported. Experiments indicate, contrary to previously held beliefs, that electric firing of such ware is commercially feasible. Feldspar and quartz, which are mixed with kaolin to form these high-quality ceramic products, are both found in the valley in abundance.

With a view to guiding agriculture and coördinating it with suitable manufacturing outlets for soil products, research is being carried on in many lines. In order to make it economically practicable for small farmers to turn from such land-destroying crops as corn and cotton to the recommended legumes and small grains, low-cost agricultural methods and machinery are being developed. An inexpensive way of curing hay has been discovered, and two types of moderate-priced threshing machines have been provided. Similar research is underway to demonstrate the use of electricity on the farm for such purposes as refrigeration, brooding, sterilizing dairy utensils, curing burley tobacco, and for energizing small, low-cost motors for operating farm equipment.

A new pressure-cooking method for extracting oil from cottonseed has been found to reduce the cooking time and to increase the yield. New ways of processing and using soy beans have been investigated, as well as methods of freezing fruits, dehydrating sweet potatoes, and refining sorghum syrups. In such lines of activity the TVA is limited to research and to experimental demonstrations, as it is prohibited from engaging in or directly promoting manufacture. In its field of endeavor, it is cooperating closely with colleges and agricultural experiment stations in the region, with the idea that those agencies will subsequently carry on the program.

APPLYING TVA FERTILIZER TO A TENNESSEE FARM

The new fertilizer, which differs from ordinary superphosphates in that it lacks gypsum, has been tested on growing crops under various conditions and appears to be effective. Its use is now being demonstrated on nearly 2,000 selected farms located in seven states. This program will continue for three years. In return for complete records, the farmers receive the fertilizer at no cost other than transportation charges.

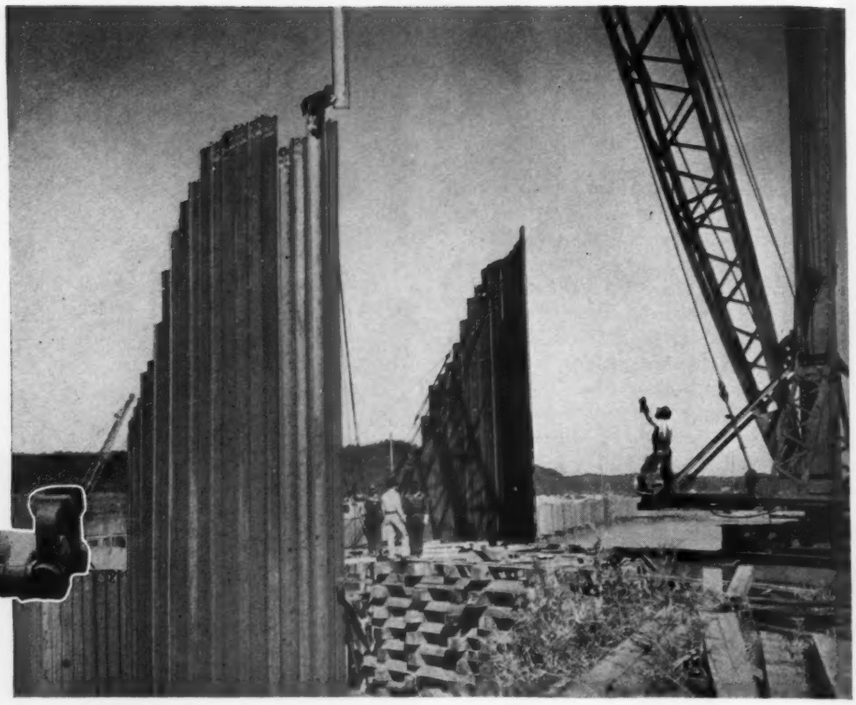
As a final step in fostering a fuller utilization of the land, the TVA has assisted various outside associations in a study of the value of coöperative processing and marketing agencies of different sorts. This work is headed by The Tennessee Valley Associated Coöperatives, Inc., which obtained a grant of Federal Emergency Relief Administration funds for the purpose. Among the recently formed organizations are a creamery association, four local cannery associations, a coöperative milling association, and a regional coöperative association which serves the canneries by maintaining centralized accounting, purchasing, and marketing services.

The foregoing account does not include all the economic and social-planning activities of the TVA, nor does it fully describe those that were mentioned. It is intended merely to indicate the kind of work that is being promoted. Doctor Morgan has declared the belief that if the Authority can go on unhindered for a period of ten years, "the process of rapid destruction of an agricultural civilization can be stopped, fertility can return, and a new stability and prosperity can be given to this region. And", he adds, "the entire nation has a stake in the outcome."

2-River Development

TVA DRILL RUNNER

Rock drills naturally are indispensable machines in excavating for the TVA dams. Both hand-held and wagon-mounted types are used in large numbers. Negroes have proved themselves good drill runners, and many of them are employed for this work. The husky darky shown here is carrying an S-49 "Jackhamer."



A COFFERDAM TAKES FORM

A workman on his lofty perch guiding a descending steel sheet pile so that it will interlock with the one last placed. The scene is the cofferdam at Pickwick Landing Dam within which a lock is now being built. Each of its 24 cells contains more than 160 piles. These were driven by floating equipment, and the cell forms were kept uniform by using a steel template designed on the job. The cells were filled with material dredged from the lock site. The cofferdam has an extreme height of 90 feet.

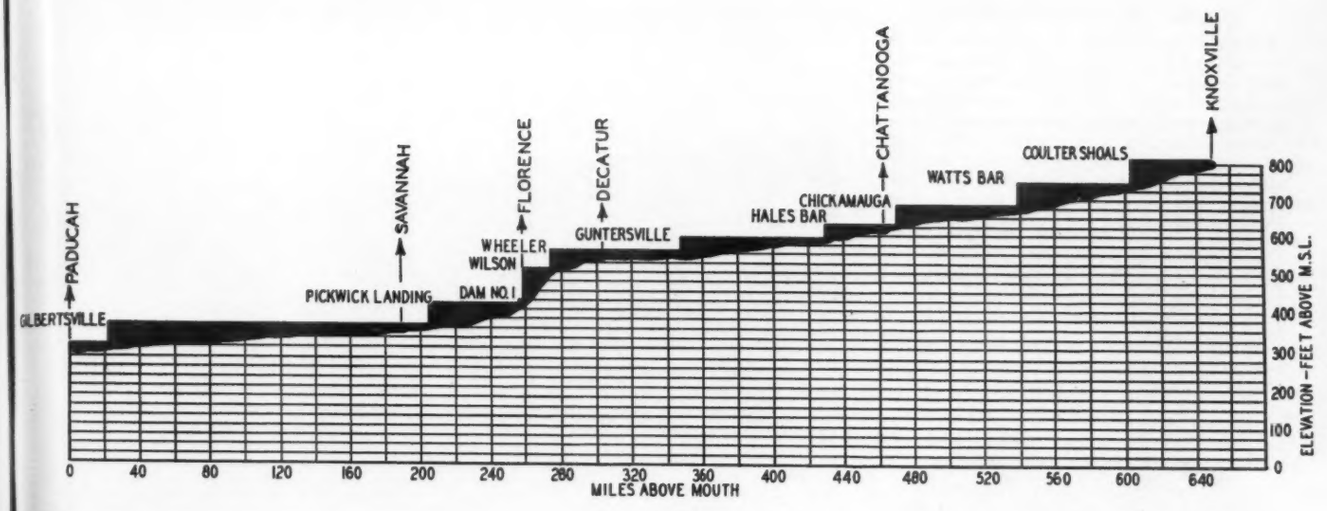
UNQUESTIONABLY the most striking aspect of the TVA program is its fundamental objective of providing for the unified development of the Tennessee River. Nothing of the sort has ever before been attempted on the same scale. The nearest approach to it is the development of the Catawba River in North Carolina and South Carolina by the Duke Power Company. In that case, however, the generation of power was the only aim, whereas the TVA plan for the Tennessee River includes navigation and flood control in addition to power generation. There is the further difference of size, as the Tennessee drainage area is about ten times that of the Catawba.

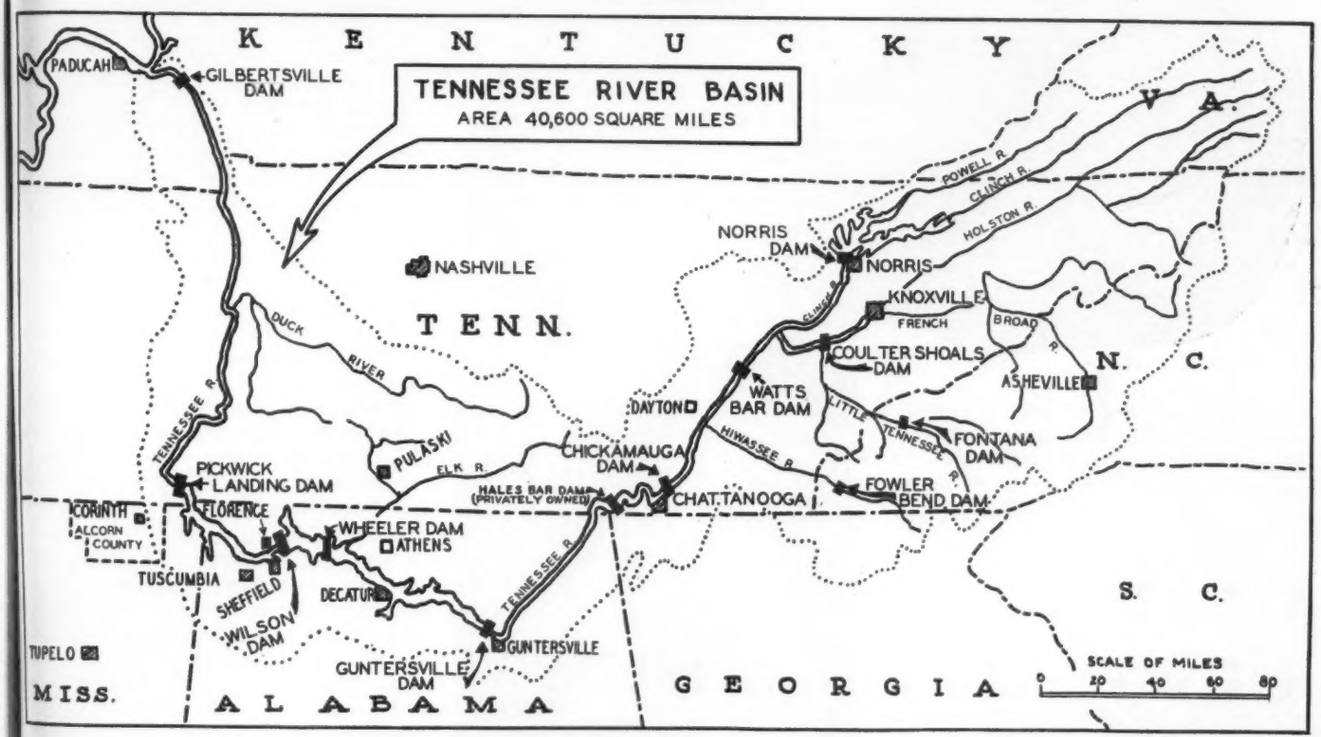
From Knoxville, Tenn., where it is formed by the union of the Holston and French Broad rivers, to Paducah, Ky., where it empties into the Ohio, the Tennessee River has a length of 650 miles. In its natural state the stream was not navigable, save in certain short stretches. The first steps towards making it navigable were taken in 1828, and during the next 102 years more than $25,000,000 was spent for that purpose. However, because these efforts were sporadic and not coördinated, they were virtually wasted. As a result, in 1930 the minimum depth at low water was 3 to 4 feet in several sections between Paducah and Chattanooga, and between Chattanooga and Knoxville it was but 1 foot. The volume of freight moved on the river in 1932 was only 949,715 tons, the lowest since 1897. The provision of a 9-foot, year-round channel will give all the Tennessee River cities economical water transportation with Ohio and Mississippi River points, and is bound to stimulate both agricultural and industrial development in the Tennessee Basin.

A part of the TVA plan is the establishment of an adequate number of river terminals at strategic shipping points and the improvement, through coöperation with state highway departments, of connecting roads which will tie together barge and truck transportation. Similar studies are underway with a view to coördinating water and rail shipments and of providing airports in relation to other mediums of transport. When these integrated facilities are completed the TVA authorities look for a marked increase in river traffic. They predict that by 1950 the annual freight movement will reach 17,800,000 tons and that shippers will save $22,800,000 as compared with present costs by railroad and highway.

While flood damage in the Tennessee Valley has never reached startling figures, it has occurred almost every year, and the aggregate loss is large. Chattanooga has suffered more than other cities. The first evidence of the relief that may be expected after the dam-construction program is finished was afforded by Norris Dam a few weeks ago when it held back sufficient water to lessen considerably the inundation of sections of Chattanooga. Flood control of the Tennessee will have a moderate but noticeable effect in regulating the flow of the Mississippi. When the latter overflowed its banks in 1927, it was estimated that from 14 to 20 per cent of the water came from the Tennessee. With all the projected storage facilities in operation, it is expected that flood crests on the Mississippi will be reduced by from 2 to 4 feet.

Control of the river is, of course, to be secured by erecting a series of dams that will transform the watercourse from Knoxville to Paducah into a succession of pools. Locks in each structure will provide for the transfer of craft to a higher or lower pool, as the case may be. There will be nine of these main-river dams. Two of them were in existence when the TVA was





TVA DAM SYSTEM

The map shows the locations of the dams which will bring about the control of the Tennessee River for the purposes of navigation, flood prevention, and power generation. The cross section illustrates how this series of structures will create a chain of lakes extending 650 miles from Paducah, Ky., to Knoxville, Tenn. Wilson and Hales Bar dams are already in place, the latter being owned by the Tennessee Electric Power Company. Pickwick Landing, Wheeler, Guntersville, and Chickamauga dams are under construction. The other main-river dams have been recommended to Congress for construction. Of the dams on tributaries, Norris is nearing completion, Fowler Bend has been authorized, and Fontana has been recommended.

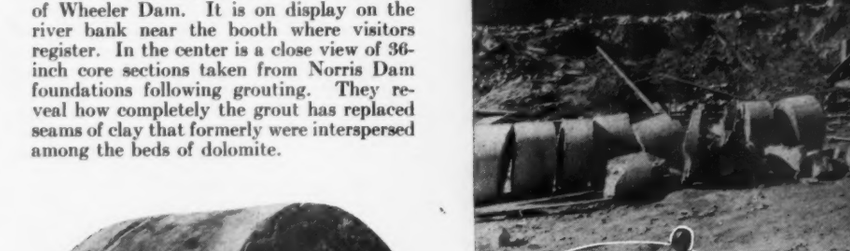
born. They are the Government-owned Wilson Dam, and the Hales Bar Dam just below Chattanooga which belongs to the Tennessee Electric Power Company. Of the remaining seven structures four are now under construction. These are Wheeler, which will soon be completed, Pickwick, Guntersville, and Chickamauga. The three others—Gilbertsville, Watts Bar, and Coulter Shoals, were recommended to Congress on March 31 of this year, and are yet to be formally authorized. An accompanying diagram shows the order in which the nine dams will be arranged, and indicates the effect that each will have in leveling the river.

In addition to the main-river dams, the plan contemplates the building of three storage dams on important tributaries and towards the head of the valley. Of these Norris Dam, on the Clinch River, has been virtually completed; Fowler Bend on the Hiwassee River has been authorized; and Fontana Dam on the Little Tennessee has been recommended for construction but not authorized. The locations of all twelve of the dams included in the unified system are shown on an accompanying map.

The scheme of regulating the river flow by coördinating all these structures has been discussed in these pages before and is so well known that it calls for only brief mention. During periods of high flow, that is, spring and summer—water will be impounded in the three storage dams just mentioned. The run-off from other sources will be sufficient in normal years to maintain the pools in the main river at a satisfactory depth for navigation and still allow the passage of enough water to meet the needs of power generation. During the low-flow period, which ordinarily starts around

CORES OF INFORMATION

Extensive use of "Calyx" core drills is being made on all TVA dams to explore foundations and to check the results of grouting. Core drilling because of its successfullness, probably will become an established procedure in safeguarding virtually all future dams of considerable size. At the right are shown two "Calyx" drills at work in a cofferdam at Norris Dam. At the bottom is a 36-inch core extracted from the foundations of Wheeler Dam. It is on display on the river bank near the booth where visitors register. In the center is a close view of 36-inch core sections taken from Norris Dam foundations following grouting. They reveal how completely the grout has replaced seams of clay that formerly were interspersed among the beds of dolomite.



September 1 and continues until December, stored water will be released from Norris, Fontana, and Fowler Bend reservoirs to augment the flow of the main river. In times of flood, it will be possible through the manipulation of gates to increase the normal impounding capacity of any or all the dams, and with that the menace to people and property will become a thing of the past.

It is readily apparent that this equalizing of the river flow will have a marked effect upon the potential power-producing capacity of the stream. No one dam can control fluctuations in flow so as to secure a high sustained volume; but a chain of impounding structures can level off the peaks and valleys and bring about a desirable and economical condition of operations. At present, the flow of the Tennessee at Wilson Dam is sometimes great enough to generate 500,000 kw. of electrical energy; but it may on occasions be so low as to provide water for only 30,000 kw. The installed capacity of the hydro-electric power plant there is 184,000 kw. Because of the inevitable variations in the river flow it was necessary to furnish a standby steam generating plant at Wilson Dam to insure the continuous production of an ample supply of power during the months of winter.

Under the planned development of the TVA, however, it will be possible to regulate the flow almost to the point desired by holding back flood waters for utilization during the season of low run-off. Norris Dam alone will have the effect of doubling the prime-power capacity of the Wilson Dam power plant during the dry season. It will do the same thing for power houses built in connection with other dams on the main Tennessee River. With Fontana and Fowler Bend structures combined with Norris Dam for storage purposes, and with the main-river dams providing storage sufficient for from twelve hours' to two weeks' regulation of the flow, it will be practicable virtually to eliminate secondary or dump power. During the wet season, only the main-river power plants will be operated: in dry seasons the water that is released from the storage reservoirs on the tributaries will first pass through turbines and produce power. Thus, the higher power houses will play the part of standby plants, and there will be no necessity for auxiliary steam plants.

It has been assumed by many persons that it is the purpose of the TVA to generate a vast quantity of power, regardless of whether or not it is needed. That is not the intention, and the TVA has repeatedly said so. In its recommendations to Congress in March for additional dams to complete the projected unified system, the power program was summarized as follows:

"The Tennessee Valley Authority, in its construction program, is providing generating facilities for the utilization of potential hydro-electric power only where they are justified from an engineering standpoint, and when it is reasonable to conclude that the power will have a market. Judgments are based on studies of existing or projected demands for power that point unmistakably to impending power shortages of serious proportions in areas that lie within transmission distances of Wilson, Wheeler, Pickwick, and Norris dams. In addition to the existing facilities installed by the War Department at Wilson Dam, generating facilities are now being installed at Norris and Wheeler dams, and provisions are being made for an installation at Pickwick Landing Dam. In order to prepare for future utilization of the potential power at the other projects, as and when marketable, provision is being made for the intake structures in the plans of all high dams now under construction, the number and size of such structures being determined by studies of the amounts of power that should be developed at these points, as a part of the ultimate possible system."

The studies referred to indicate that there will be a market for a large proportion of this power in the immediate future. On this point the 1935 report of the TVA states: "The estimates of the Tennessee Valley Authority and of the Federal Power Commission indicate a need for additional capacity in 1937 amounting to 300,000 kilowatts. This compares with new capacity of 236,000 kilowatts now in process of installation by the Tennessee Valley Authority. It appears that these estimates have been entirely confirmed by the facts. In this area, from 1902 to 1912, production of electricity grew at the compound rate of 20 per cent per year; during the following decade, the growth was at the rate of 11 per cent; and from 1922 to 1932 at 8 per cent. From 1926 to 1929, annual production increased 48 per cent. The 1929 peaks have already been exceeded during the recovery stage following the depth of the depression. Generation for the year ended October 1935 in the State of Alabama was 16 per cent above the 1929 total. In Tennessee, the Tennessee Electric Power Company, which is the largest utility in the state, has experienced greater demands than ever before. In 1935 the peak was 10 per cent above the 1929 peak of this company. The system peak demand, which in 1929 was 128,000 kilowatts and which dropped in 1932 to 99,000 kilowatts, has risen already in 1935 to 140,000 kilowatts, which is just about the 1937 peak demand forecast by this company. In other words, this company in 1935 had already reached the load forecast by it for 1937. Production curves for various states, made up from the United States Geological Survey Reports of Production of Electricity for Public Use, show the same trend as the demand curve of the Tennessee Electric Power Company. . . . . The fall of 1935 has turned out to be dry and indicates what may occur in 1936, should a dry year be experienced. Certain companies have already met an acute shortage. The Tennessee Electric Power Company and the Alabama Power Company in October, 1935, made heavy demands on the Muscle Shoals plant of the Authority and also operated many steam reserve plants for a substantial part of their needs. Wilson Dam production in the six months since the close of the fiscal year, June 30, 1935, has several times exceeded all previous records of output and demand."

In predicting a continued growth in the consumption of power, the TVA is, of course, counting upon acceleration as the result of its efforts. An integral part of the broad program is to promote a greater use of electricity on farms and in homes and also to increase the industrial load by demonstrating that raw materials, adequate and inexpensive power, and a plentiful labor supply combine to make the Tennessee Valley a desirable area for the location of various processing and manufacturing establishments.

SITE OF GUNTERSVILLE DAM

The underlying TVA theory as to the economics of power production is that low rates will increase consumption and that this, in turn, will reduce the unit generating cost. Although it has thus far been applied on only a small scale, the theory seems to be working. For example, a substantial gain in the use of power has been recorded in all communities which have contracted with the TVA for service. The most striking example is Tupelo, Miss., with an increase of 164.69 per cent from March, 1934, to June, 1935. The average consumption per customer per month jumped from 49 kw-hrs. to 112 kw-hrs. At the same time, because of the lower rate in force, the average monthly bill dropped from $3.60 to $2.30. As an illustration of the enormous possibilities that exist for increasing the use of electricity, the TVA points to the record at the Town of Norris, where all practicable services, even heating, are being done with electric power. In its 150 houses the average consumption is from 20 to 25 times that of the average electrified home in the country at large.

On the basis of the studies made thus far the TVA engineers have concluded that provision should be made for an aggregate generating capacity of approximately 1,937,000 kw. in the design of the eleven dams included in the ultimate power system. Of that total, 1,607,000 kw. would be developed at dams on the main river and 330,000 at dams on the tributary streams.

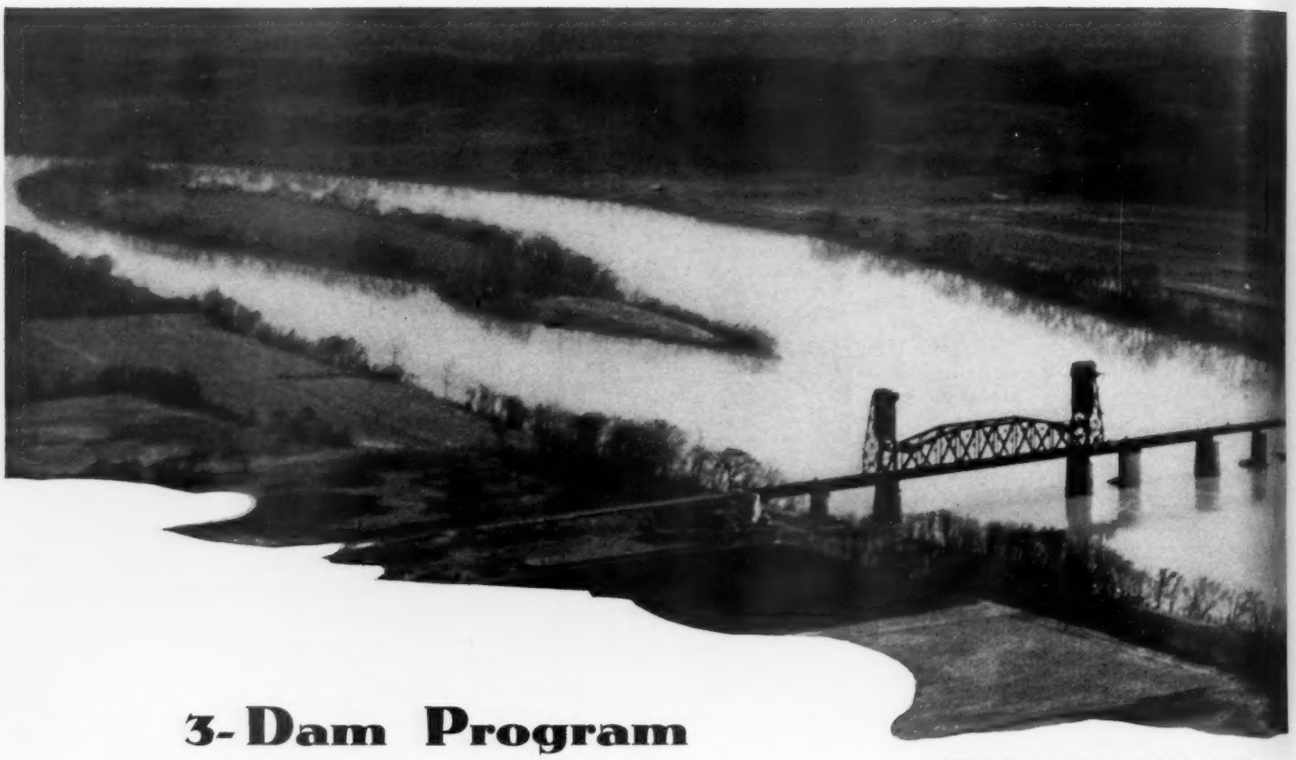
The scheduled installation at individual dams is as follows:

Project	Kilowatts
Coulter Shoals	54,000
Watts Bar	150,000
Chickamauga	160,000
Guntersville	82,000
Wheeler	256,000
Wilson	445,000
Pickwick Landing	204,000
Gilbertsville	256,000
Norris	100,000
Fowler Bend	80,000
Fontana	150,000

With these facilities, together with the ultimate obtainable regulation of the river flow by the integrated system of dams, it is computed that it would be possible to produce 660,000 kw. of prime or continuous power. As previously mentioned, it is intended to install only part of this generating equipment now and to add more if and when the market for power requires it. The following tabulation shows the prime or continuous generating capacity that will be available at various stages of partial development of the system. In the first column is listed the equipment at only Norris, Wheeler, and Wilson dams as now provided and being provided, but with the addition of river regulation through storage at other dams. The second column gives the full and economical installation of generating equipment to be made at all dams.

Stages of Development	With Present Installations* Kilowatts	With Projected Future Installations Kilowatts
Wilson, Wheeler, Norris	205,000	205,000
Wilson, Wheeler, Norris, Pickwick	205,000	265,000
Wilson, Wheeler, Norris, Pickwick, Guntersville, Chickamauga	215,000	355,000
Wilson, Wheeler, Norris, Pickwick, Guntersville, Chickamauga, Fowler Bend	225,000	400,000
Wilson, Wheeler, Norris, Pickwick, Guntersville, Chickamauga, Fowler Bend, Fontana	.....	510,000
Wilson, Wheeler, Norris, Pickwick, Guntersville, Chickamauga, Fowler Bend, Fontana, Watts Bar, Coulter Shoals, Gilbertsville	.....	660,000

*Wilson, 184,000 kw.; Wheeler, 64,000 kw.; Norris, 100,000 kw.; with no generating equipment at other projects. Wilson Dam standby steam plant excluded.



3-Dam Program

CHICKAMAUGA DAM SITE

This projected $32,000,000 structure will span the Tennessee River at the near end of the island. The site is eight miles upstream from Chattanooga, for which city the dam will afford considerable flood protection. The location was determined after 25,000 feet of exploratory drilling had shown weaknesses in the foundation rock at other proposed sites. The construction will involve the diversion of North Chickamauga Creek into the river below the dam. The bridge in the foreground carries the tracks of the Southern Railway.

THE entire TVA scheme for converting the Tennessee River into a chain of connected lakes by building dams at strategic points was unfolded in March when recommendations were made to Congress covering the locations and estimated costs of the four remaining structures in the system that had not previously been definitely decided upon. With the constitutionality of the Authority a settled matter by virtue of the Supreme Court decision of February 17, there appears to be little doubt that the construction program will proceed without interruption. In addition to the main-river dams, the system will of course include the three structures on tributaries that were mentioned in the second part of this account. It will likewise include Wilson Dam, which the TVA inherited, and the Hales Bar Dam of the Tennessee Electric Power Company. The latter structure may or may not be purchased and incorporated in the system. In any event, the TVA has stated its intention of raising the level of the Hales Bar pool and also of doing considerable dredging there to provide a 9-foot channel, the estimated cost of these undertakings being $4,500,000. The names, locations, and estimated costs of the ten dams now under construction or projected are given in the table below.

It is proposed to stagger the work, and under this plan the last of the structures would be started in 1941 and the system would be completed in 1944. By taking up the several projects in suitable order, TVA heads point out, the continuous use of skilled men and of equipment can add greatly to the economy of building operations. The cost of each dam, as given, includes not only the construction items but also the purchase of the reservoir areas, and their clearance.

The remainder of this article will be devoted to a brief review of the progress at the dams now underway. Such a description should logically start with Norris Dam, as it was the first to be begun and is the farthest along. The sluice gates through which the Clinch River had been flowing were closed with public ceremonies on March 4, when a lake began to form behind the 265-foot-high concrete structure. At normal high-water elevation it will have a surface area of 34,200 acres. By raising the spillway gates, an additional 14 feet of depth can be obtained. It is not expected to utilize this reserve capacity save in case of floods. Approximately 400 cfs. of water is being passed through the dam to supply sanitation requirements downstream. In years of normal run-off in the Tennessee River system, water will be stored behind Norris Dam from February 1 to September 1. During the other months it will be released to augment the volume in the main river.

Norris Dam is 1,872 feet long at the crest and contains approximately 1,000,000 cubic yards of concrete, all of which was made from aggregates quarried adjacent to the site and reduced to suitable sizes, including the sand. Construction was done in two stages. One half of the river bed was first unwatered with the aid of a timber-crib cofferdam, excavation carried to grade, and the foundation poured to a level slightly above the natural river bed. This cofferdam was then removed and another one, of concrete, erected in the second half of the channel. Within this protecting barrier the work of excavating and pouring the foundation was duplicated, the river meanwhile being allowed to flow over the con-

Name	Stream	Status	Estimated Cost
Gilbertsville	Tennessee	Recommended	$60,000,000
Pickwick Landing	Tennessee	One-third completed	28,000,000
Guntersville	Tennessee	Started	29,000,000
Wheeler	Tennessee	Nearing completion	29,000,000
Chickamauga	Tennessee	Started	32,000,000
Watts Bar	Tennessee	Recommended	31,000,000
Coulter Shoals	Tennessee	Recommended	20,000,000
Norris	Clinch	Nearing Completion	36,000,000
Fowler Bend	Hiwassee	Authorized	15,250,000
Fontana	Little Tennessee	Recommended	29,000,000
		Total Estimated Cost	$309,250,000

STARTING WORK ON PICKWICK LANDING DAM

This structure will be erected in three stages. The first involves the building of the 110x600-foot, 67-foot-lift lock, the beginning of which is shown here. The site was dredged with floating equipment, after which the cofferdam was constructed. Its riverward side contains 24 cells formed by driving interlocking steel sheet piling with floating equipment. The ends are steel-sheet-pile cut-off walls. The cofferdam required 1,985 tons of steel. The first concrete in the lock walls, which will rise to a height of 80 feet, was poured by a crane traveling on wide-gauge railroad tracks, as pictured here. Meanwhile equipment was assembled for placing concrete in the forms by belt conveyor. The framework of the concrete mixing plant is seen on the left bank, and in the distance is the cement silo which was formerly used at Norris Dam.

crete already in place. When the last half of the foundation had been brought to the level of the first, the second cofferdam was removed and the stream thereafter passed through two 50-foot openings which were purposely left while the remainder of the structure was carried upward. The final closure was made in the low-water period of 1935 by bulkheading these two openings alternately and by pouring a 5-foot lift of concrete in the inclosed space. When the water reached a depth of 40 feet above the river bed, the river was diverted through eight permanent sluice-gate openings near the base of the dam.

Concrete was placed by means of two 18-ton-capacity cableways of 1,925-foot span and having movable head and tail towers that ran on 42-foot-gauge tracks. It was delivered in 6-cubic-yard buckets and poured in 5-foot lifts, the blocks normally being 56 feet wide and the specified thickness of the dam. Forms were made up from wood panels 5 feet high and 14 feet long, and were used twenty or more times. They were handled by two self-propelled gasoline-powered cranes, thereby keeping the cableways free for their prescribed work.

All concrete was vibrated in the forms, and in connection with this operation it was discovered that by speeding up the vibration it was possible to use a stiffer mix and, consequently, to realize a saving in cement. This practice is being followed at Wheeler and Pickwick dams; and at the former it was found that the normal cement proportion could be reduced by as much as 25 per cent. The most effective rate of vibration, as determined at Norris, was about 4,500 rpm. In electric vibrators, which normally ran at 3,600 rpm., the increased speed was obtained by installing frequency changers and stepping up the current from 60 to 80 cycles per second. The pneumatic vibrator was regulated by suitably setting the governor or by changing the air pressure.

No artificial means of cooling the concrete were employed, but extensive provision has been made for studying the rate at which the heat is dissipated from the mass with a view to obtaining information that will be of value in the future in building mass-concrete structures. One hundred and sixty electric-resistance thermometers were embedded in the concrete and the bedrock. Each consists of a coil of fine copper wire inclosed in a moisture-proof case and connected by copper lead wires to a central terminal board in one of the galleries. In order to measure the rate of opening of the contraction joints between blocks and the extent of the openings, there were installed 47 electric-wire joint meters, each consisting of a fine steel wire stretched between the ends of an oil-filled expansible brass tube. As a joint opens, the tension on the wire increases, and by measuring the resultant change in electrical resistance the amount of the opening may be determined. These meters are sensitive to changes of as little as 0.0007 inch and have a range of 0.25 inch. Strain meters similar to the joint meters will show a change in length of as little as four-millionths of an inch. These are embedded directly in the concrete in groups arranged so as to indicate at six points the strain in any direction at right angles to the axis of the dam and in the horizontal plane parallel to the axis. Seventy-two of these strain meters have been provided.

In a previous account (August, 1934) we described the painstaking steps that were taken to consolidate the foundation rock, which consisted of horizontally bedded dolomite having interpolated seams of clay. The general procedure was to drill holes 40 feet deep on 5-foot centers with wagon drills and to wash the clay seams from between the dolomite beds by introducing air and water into alternate holes. Neat cement grout was pumped into all holes, more than 115,000 bags being used. After the grout had set, "Calyx" core drills were employed to check the results. Numerous 5-inch and 36-inch cores were extracted for inspection, and men were lowered into the 36-inch holes to examine

the strata in place. In all cases it was found that the clay had been completely replaced with grout. A line of core holes 100 to 200 feet deep was also drilled along the upstream face of the dam and grout forced into them under high pressure after 100 or more feet of concrete had been poured in the dam. When that structure was nearly completed, 3-inch "Calyx" core-drill holes were drilled at intervals of 10 feet from the gallery at elevation 880 down through nearly 100 feet of concrete and into the bedrock. Similar holes of 5½-inch diameter were drilled from the gallery at elevation 840. High-pressure grouting was applied to both these sets of holes. Pipes for the subsequent grouting of contraction joints were carried to the top of the structure. Outlet openings were provided on 5-foot centers.

The two 56,000-kva. generating units are now being installed in the power house, and it is expected that the entire undertaking will be completed by August 1. The work was started under the direction of Ross White, as superintendent. When Mr. White was made general construction superintendent for the TVA, his work at Norris was taken over by F. C. Schlemmer, who had served as one of his assistants. Barton M. Jones is chief engineer.

Wheeler Dam, begun in November, 1933, is likewise nearing completion. The first of the two 36,000-kva. generators which will comprise the initial installation will be in place by July 1, and the expectations are that it will be ready for commercial operation by August 1. This structure, including its lock, is 6,335 feet long and is made up of a power house and of non-overflow and spillway sections. It is at the head of the slack water from Wilson Dam and will raise the normal level of the river 50 feet. Its reservoir will extend upstream 86½ miles and will have a normal capacity of 1,050,000 acre-feet, with a further reserve capacity of 500,000 acre-feet for flood control.

The lock at one end of the dam was built by private contract and the remainder of the structure by TVA forces. At the height of work more than 5,000 men were employed, which made it the largest construction job in progress in the country at the time. The work of crossing the river went on progressively by the aid of five cofferdams. The concrete, about 650,000 cubic yards, was placed with floating equipment. This project was notable for the fact that 3,600 individual pours of concrete were required, a circumstance which entailed a vast amount of form work.

The spillway section is 2,700 feet long and consists of 60 gates each with a 30-foot span and with a 15-foot pier between gates. After the construction operations had been carried across the river the flow was passed through this spillway section. All of it was concreted up to elevation 506, which is 1 foot above the normal level of the Wilson Dam pool on the downstream side. The piers were then built up to crest elevation 541 in 5-foot lifts. Each of these 60 spillway openings is being fitted with a Tainter gate 40 feet wide and 15 feet high.

Wheeler Dam was started with L. H. Huntley as superintendent and W. M. Hall as chief engineer. Mr. Huntley has since been transferred to Pickwick Landing Dam and his place at Wheeler was taken by G. A. Jessup.

Pickwick Landing Dam is the next below Wilson Dam and will back up the river 53 miles to the latter structure. It is located 207 miles upstream from the Tennessee-Ohio confluence and near the Mississippi state line. It will have a total length of 7,715 feet made up, from north to south, of 890 feet of earth-fill section, 201 feet of concrete non-overflow section, a concrete power-house intake structure 566.5 feet long, a concrete spillway section 1,555.5 feet long, a navigation lock 220 feet across, and an earth-fill embankment 4,682 feet long.

Following core-drilling, construction was begun in November, 1934, and is now about one-third completed. Preliminary operations consisted of building a black-top road some 15 miles long from the nearest state highway to the site, and of erecting a modern village to house the workers. As both whites and negroes are employed, facilities are available for each group. These consist of fifteen permanent houses, 110 temporary houses, five bunk-houses made up of rooms that accommodate two men each, cafeterias, recreation buildings, schools, a fire station, a hospital, and office buildings. The high school is attended by students formerly enrolled in the Town of Shiloh, Tenn., in addition to the children of the dam employees.

The initial construction work on Pickwick Landing Dam was centered on the earth-embankment sections on either side of the river, which has a width of about 1,400 feet at this point. A trench 17 feet deep was first excavated along the line of the embankments. Steel sheet piling was next driven in the bottom of the trenches to rock to prevent underground seepage. The trenches were then refilled and became parts of the impervious clay-core centers. The embankments range up to 350 feet thick at their bases, the thickness and height decreasing as they approach higher ground. They are 20 feet thick at the crest. Most of the material for these earth sections was dredged from the river bottom and from areas that are to be occupied by the lock on one side and the power-house structure on the other. This material was pumped by the 800-hp. electric suction dredge boat *Dallas*.

The building schedule specifies that the remainder of the work be done in three stages. The first stage, which is now underway and which will continue throughout most of the year, is the lock construction. The second stage includes the power house, the non-overflow section, and one-fourth of the spillway section. A cofferdam to inclose that area will be erected this year. The third and final stage calls for the closing of the central gap and for the finishing of the spillway section. Completion is set for the end of 1938.

Foundation rock is uniformly good, consisting of horizontally bedded limestone. A soft-blue variety at the surface is underlain by a harder white variety. At the lock site it was necessary to excavate an average of only 2 feet to secure a sound footing, and borings indicate that only 5 feet will have to be removed farther out

AIR-CONTROLLED BUCKET

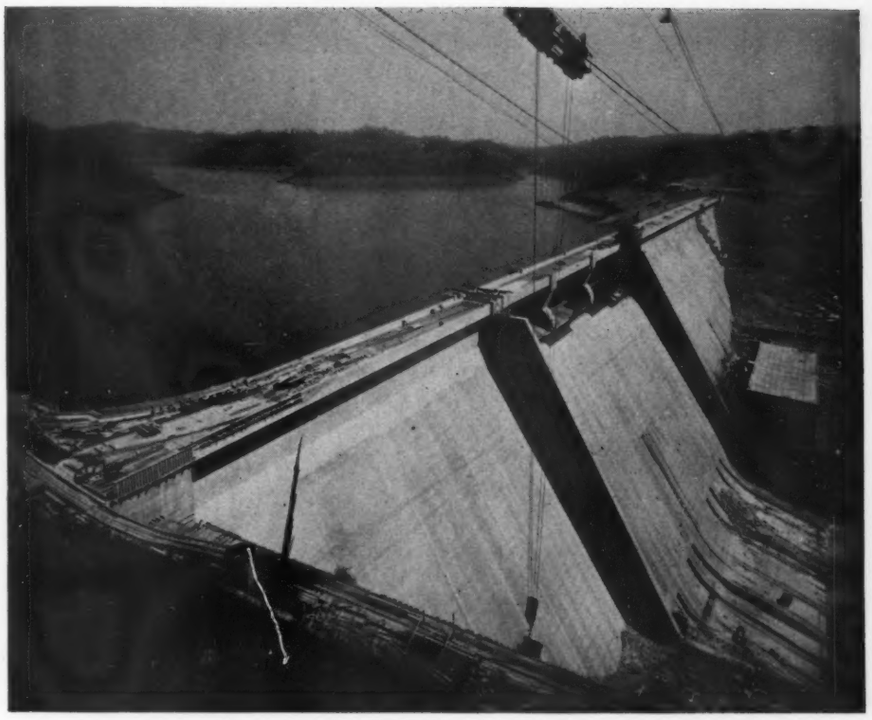
A miscellaneous use of compressed air at Norris Dam was for operating the mechanism that opened the 6-cubic-yard, bottom-dump concrete buckets. The air was applied at the pipe extending from the lowest corner of the bucket. The workman is holding the air hose with which the connection was made.

in the river. At each of the four corners of that area a 36-inch hole 40 feet deep was drilled with a "Calyx" core drill to permit inspection of the underlying strata.

Pickwick Dam is advantageously situated as regards water transportation for much of the essential construction materials and equipment. Cement is delivered from eight different concerns by rail to Sheffield, Ala., and barged to the dam site. It is unloaded pneumatically into an overhead steel silo and then pumped to the concrete mixing plant by an air-activated blower system. Concrete aggregates are obtained about a mile upstream from the dam site and are washed and classified before being loaded on barges. At the dam site they are dumped by clamshell buckets into a hopper feeding a conveyor belt that carries them to a Kern circular storage system. The various sizes are stored around its centrally located tower from which extends a belt-conveyor system that carries them to the concrete mixing plant and that is protected to the edge of the storage area by a concrete tunnel. The mixing plant is located adjacent to the lock area. It contains three 2-cubic-yard mixers and has a normal capacity of 2,000 cubic yards per day. Pouring of the concrete in the lock was started with material that was supplied by small mixers and that was placed by means of cranes traveling on 28½-foot-gauge tracks. Concrete now reaches the lock area by belt conveyors running from the central mixing plant to a track hopper. The buckets are filled under the hopper and are swung to the forms by whirleys. For the construction of the power-house section, on the opposite side of the river, it is probable that a cableway will be erected.

Pickwick Dam will have a maximum height above the foundation of 110 feet. Its reservoir will have a normal total volume of 807,000 acre-feet, and it will be large enough to store an additional 416,000 acre-feet for flood control. The discharge capacity will range from 560,000 cfs. to 850,000 cfs., depending upon the water-surface elevation. The lock will have a possible maximum lift of 67 feet in one stage, which will make it the highest single-lift structure of its kind. The chamber will be 110 feet wide and 600 feet long; its total length including guard walls will be 2,009 feet; and fifteen minutes will be required to fill it. No installation of generating equipment is planned at this time, but provision will be made for the placing of six 34,000-kw. units later on. Estimates of the principal quantities of materials to be handled during the construction are: hydraulic excavation, 2,617,700 cubic yards; dry excavation, 11,332,235 cubic yards; rock excavation, 238,400 cubic yards; steel sheet piling, 12,002 tons; concrete, 645,600 cubic yards.

This is the first TVA dam to be designed by its own engineers. In order to gain a quick start, Norris and Wheeler dams were designed by the U. S. Bureau of Reclamation, which had an organization available. The various other structures in the system, however, will be the work of the TVA personnel throughout. L. H. Huntley is construction superintendent at Pickwick Dam, A. L. Pauls is project superintendent, and R. F. Olds is construction engineer.



NORRIS DAM STARTS TO WORK

Gates of the eight sluiceways (the rectangular slots in the base of the dam) were closed on March 4, when storage of water began. The line of trees indicates the maximum surface elevation of the reservoir. This structure on the Clinch River was started in October, 1933. The power house, where two 56,000-kva. generators are now being installed, is shown at the right center.

Guntersville Dam, located nine miles downstream from Guntersville, Ala., and 349 miles from the Tennessee-Ohio junction, was authorized on November 27, 1935, and is now in the first stages of construction. Driving of the steel sheet piling for the lock cofferdam was started in April. It will have a length of 3,980 feet, of which 2,512 feet will consist of an earth fill on either side of the central concrete structure. It will be 80 feet high and will form a reservoir 82 miles long and having a storage capacity of 951,000 acre-feet of water. It will have a 60x360-foot lock with a single lift of 40 feet. No generation of power is contemplated for the present, but the plans provide for the possible future installation of 120,000 hp. The structure will call for the placing of 326,000 cubic yards of concrete and 550,000 cubic yards of earth. The work there is in charge of G. A. Jessup, superintendent.

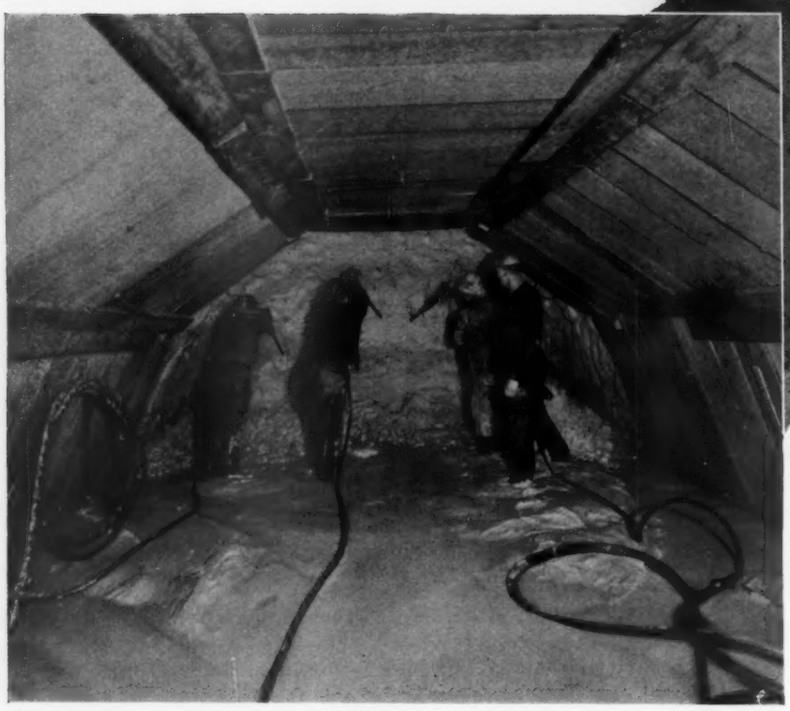
Chickamauga Dam, situated seven miles upstream from Chattanooga, Tenn., is in the initial stages of construction, having been authorized on December 31, 1935. It is similar in type to Pickwick and Guntersville dams, and will consist of a central concrete structure flanked by earth dikes. It will have a total length of 5,685 feet, of which 1,625 feet will be concrete; will have a maximum height of 104 feet; and will back up the Tennessee River for a distance of 76 miles. Its reservoir will impound 742,000 acre-feet of water. It will have a 60x360-foot lock with a single lift of 55 feet. Provision will be made for the installation subsequently of generating equipment of 230,000-hp. capacity. None is to placed for the present. The driving of steel sheet piling for a cofferdam to unwater the lock site was started in April. Construction will be carried on in three stages: the spillway is to follow the lock, and the power house is to be erected last. Lee G. Warren is project engineer, E. M. Whipple is construction superintendent, and J. K. Black is assistant engineer.

Approximately $1,000,000 has been spent on preliminary investigations and plans for Fowler Bend Dam, to be located on the Hiwassee River; but no date has been set for the beginning of construction. It will be similar to Norris Dam, as it will occupy a comparatively narrow valley and will be 300 feet high.

Of the dams recommended to Congress but not yet authorized, Fontana Dam, on the Little Tennessee River, is of special interest because of its projected height of 450 feet. If it is built it will be among the higher concrete dams of the world; and residents of the Tennessee Valley have already nicknamed it "Boulder Dam of the East."

Unusual Equipment Serves Tunnelers---

A. M. Hoffmann



BLASTING AND PICKING

In the Minneapolis section of the system, blasting was the preferred method of tunneling. Holes were drilled for the most part with rock drills, but in some cases they were made with a single jet of high-pressure air. Headings were advanced 5 feet per round with light charges of explosives. Pictured at the left is one of the two headings advanced through the St. Peter sandstone from the bottom of the 200-foot shaft. The major part of the excavating of this 5,300-foot stretch was done with fifteen L29 air-operated "Pickhamers." Timbering of the arch was required only in the larger tunnel sections of the sewage-disposal system, such as the one shown.

THE cities of Minneapolis and St. Paul are engaged in the building of a joint sewage-disposal system that presents some unique aspects. The work is being done by the Minneapolis-St. Paul Sanitary District which was created for the purpose and with funds provided by the Public Works Administration. It involves the construction of approximately 41 miles of sewers—18 miles by Minneapolis, 14 miles by St. Paul, and 9 miles by the District—and will consist of 600 feet of siphon, 5.6 miles of open-cut section, and 35.4 miles of tunnels. These vary considerably in shape and size, the largest being circular and having a diameter, after lining with concrete, of 13 feet 10 inches. It is the tunneling phase of the project that is of especial engineering interest.

The Twin Cities are underlain by what is known as St. Peter sandstone, a white, friable stone that is stable in the undisturbed state but presents no excavating problems. It is through this formation that the tunnels are for the most part being driven not with the conventional equipment but with pneumatic "Pickhamers," blasting, and with jets of compressed air and, in one case, of water. The material is brought down in the form of a fine sand; and in its removal we have another departure from accustomed tunneling practices. The spoil is mixed with water and disposed of by pumping. This unusual method of handling muck has been made possible by the use of rubber-lined casings and by fitting the pumps employed with rubber bearings and impellers, the latter being mounted on steel disks. When pumping was first tried, the parts subjected to the highly abrasive action of the sand wore out so quickly that the upkeep costs were prohibitive. Water-lubrication also serves to lessen abrasion, but it lowers the capacity of the pumps.

As a fairly typical example of the tunneling operations it will be sufficient for the present purpose to describe the work done on Contract 105—a 5,300-foot section that constitutes a part of the main line in St. Paul and that has been carried through the sandstone formation. This section is circular in form and has a finished inside diameter of 11 feet 9½ inches—the reinforced concrete lining being 12 inches thick. It was driven by the heading-and-bench method and from two headings which were advanced simultaneously in opposite directions from the bottom of a 200-foot shaft.

The cycle of operations was as follows: The first step was to undercut the face, and this was done with amazing rapidity with high-pressure air issuing from a 5-jet manifold at the end of a ¾-inch pipe. Next the face was advanced from 4 to 5 feet and a preliminary bench cut made at the same time. This work was done with the "Pickhamers," which were found to be especially well suited for it and enabled the men to bring down slabs several inches thick, the material crumbling up into fine sand. The entire section of a little more than a mile was driven without the need of firing a single shot.

As fast as the heading was advanced the arch was supported with 3x10 timbers that were laid flat in five segments and rested on wall plates set on shoulders left along either side of the tunnel when removing the bench. These shoulders were cut away when the lower side walls and invert were trimmed and a trench was dug for the laying of a tile underdrain. Heavy flows of

Courtesy, Engineering News-Record

water seeped in through fissures in the rock, and these were often sufficient to wash the loosened sandstone down the walls into two narrow ditches, one on each side of the bench. Where the seepage was not adequate, the material was brought down by flushing with a hose. The muck from the trenches was collected in a pool that was generally located about 25 feet back of the heading.

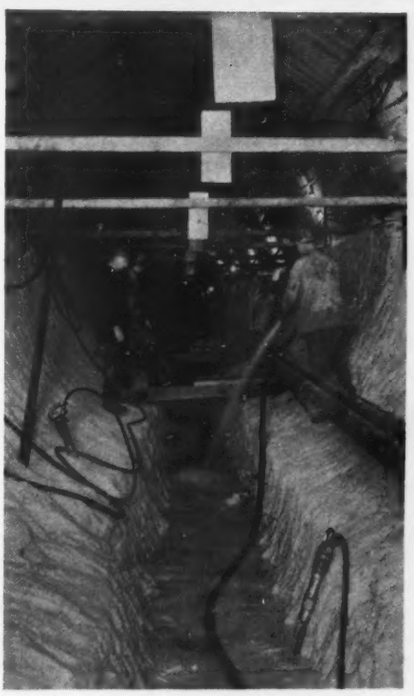
Three centrifugal pumps were used to handle the spoil from each heading: one at the pool and two at the shaft. From the former the fluid muck was carried to the bottom of the shaft through a 4-inch line which reached a maximum distance of 3,600 feet, the shaft not being centrally located. Thence it was boosted through 4-inch risers to the surface, where it was separated in three overhead bins adjacent to the shaft, the water passing over a waste weir and draining into a nearby sewer. As soon as the sand in one of the bins was sufficiently dry for dumping, it was discharged through bottom gates into trucks for disposal. Drying was effected in about five minutes by operating two well points with which each bin was provided. The bins were constructed of wood and were lined with steel.

The pumps were operated continuously, the speed being regulated according to the consistency of the mass and the rate of flow which, necessarily, varied continually. They were designed to pump against a 65-foot head and, with one exception, were driven by 30-hp. motors. That was when the delivery line from the heading farthest away from the shaft had been lengthened to 1,700 feet. Then a 50-hp. motor took up the work of operating the rail-mounted pump at the collecting pool, thus making it possible to dispense with the services of additional boosters and to transfer the muck the entire 3,600 feet to the shaft in one stage. Mucking operations following trimming of the side walls and invert, digging of the drain trench, etc., proceeded in the same manner.

Although the ground water encountered in the particular stretch being described at times reached a flow of 3,200 gpm., it did not greatly interfere with progress. The surplus or clear water from the upper heading drained naturally, while that from the lower one had to be pumped a total distance of 1,500 feet to the shaft, where it was boosted to the surface through one 4-inch and two 8-inch risers by six electrically driven pumps, two with a capacity of 1,400 gpm. each and four with a capacity of 500 gpm. each.

With the exception of one section, which is to be awarded shortly, all contracts for the Minneapolis-St. Paul Sanitary District work have been let, and the intercepting system is approximately 75 per cent completed. It includes a thoroughly up-to-date treatment plant, which is being built by the Sanitary District on the east bank of the Mississippi River near the southern limits of St. Paul. Through this the sewage from the Twin Cities will pass, thus ending the pollution of the local waters that has for years been both a nuisance and a menace to those communities.

Work on the project was begun in July of 1934, and is being done under the supervision of C. C. Wilbur, chief engineer for the Minneapolis-St. Paul Sanitary District; F. Paul, city engineer of Minneapolis; George M. Shepard, city engineer of St. Paul; and William N. Carey, project engineer for the Public Works Administration.

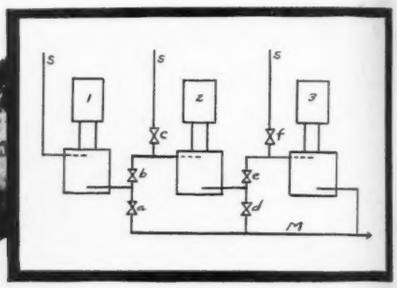


MUCKING OPERATIONS

The drain trench, which was backfilled with gravel as soon as the tile was laid. The excavating of the trench and the trimming of the lower walls and invert were done simultaneously with "Pick-hamers." Mixed with water to the proper consistency, the spoil was delivered to the boosters at the shaft by a 4-inch centrifugal pump with rubber bearings and impellers. To still further lessen abrasion the pump was lubricated with water, which tended to reduce its capacity from 500 to 400 gpm. At the top is another view of the working face showing the arch timbering and how the excavated sandstone was washed down into narrow ditches and allowed to collect in a pool back of the bench.

Compressors Drive Pumps 60 Miles Away

Elton Sterrett



IN OPERATION

The upper picture shows the open-air installation of three 10x6x10 piston pumps that was operated by high-pressure natural gas in lieu of steam. In the bottom view are seen the exhaust lines from the pumps extending out over a creek, and also the intake pipes that supplied the water that was pumped. What appear to be white clouds are actually glowing, scorching flames of ignited gas being exhausted at 20 pounds pressure. Despite this intense heat, the cooling caused by the expansion of the gas kept the pipes covered with frost. The diagram at the right indicates the layout of the pumps, which are designated by numerals. Suction lines are marked "S." Discharge gates are denoted by "a" and "d"; compounding gates by "b" and "e"; and intake gates by "c" and "f." The pumps discharged through the 4-inch line, "M," leading to the pipe line under test.

COMPRESSORS more than 60 miles away from a pumping site were used to drive three 10x6x10 duplex pumps in testing a 57-mile, 8-inch main destined to become a crude-oil pipe line. As the laying of the pipe was a contract job, one of the requirements was a hydrostatic acceptance test of the entire line at a pressure of 1,000 pounds per square inch. To build up this pressure, and at the same time to pump expeditiously the 785,000 gallons of water needed to fill the line, three duplex pumps were connected so that they could be used in parallel or, simply by manipulating six gates, compounded to raise the high-test pressure in three stages.

According to the original plans the three steam pumps were to be operated under the power for which they were designed. It was necessary to make a change, however, when it was found that adverse weather conditions and general oil-field congestion would seriously delay the work of bringing in and setting up the boilers. In this emergency, a 16-inch natural-gas main, which was under a pressure of 375 pounds per square inch and which was to furnish fuel for driving the engines in the crude-oil pumping station, was pressed into service. A 4-inch branch was tapped into the gas main and run over the ground to the point where the three pumps were located, where it was piped, with suitable valves, directly into what would normally have been the steam chests of the pumps.

Admitted under its line pressure, the gas was worked expansively in the power cylinders and was discharged through 2-inch lines led out over a creek that served as a water supply for the pump suctions. By means of a ¼-inch line and valve, a pilot light applied flame continuously to the discharge orifices, and the gas, exhausting at a pressure of around 20 pounds per square inch, was burned in long flares which intermittently blazed fiercely and dwindled to a mere glow. Although the heat of this flaming exhaust was almost unbearable, the exhaust lines were covered with as much as 2 inches of frost by reason of the rapid expansion of the high-pressure gas as it was used.

When the line was completely filled, with the three pumps working in parallel, the suction valves shown at "c" and "f" in the sketch were closed, as were the discharge valves "a" and "d," all of which had been open up to that time except when minor adjustments called for temporarily taking one pump off the line. Then valves "b" and "e," formerly kept closed, were opened to allow each pump in the row to discharge directly into the intake chamber of the one standing farther up from it in the pressure scale.

When the pumps were shifted over from parallel to series operation, it was interesting to see how quickly those units, which had up to that time worked at varying rates and with no two in step, quickly fell in line as the discharge pressure of each became the suction pressure of the next. The three pumps operated as though invisibly connected by positive, mechanical means. By thus changing over the pump suction and discharge connections, the pressure was stepped up to the relatively high maximum demanded for the test without overloading the power end—the work of each pump being simply to increase the pressure of the water handled through it.

When the test was satisfactorily completed, the bill for the natural gas used was compared with the lowest bid on the job of moving in the boilers, and it was discovered that the cost of the emergency power was less than the sum that would have been expended for hauling the boilers to and from the pumping site.

The natural gas that served as power in this novel application was boosted to its standard line pressure of 375 pounds per square inch in a compressor plant situated at a point on the 16-inch main 64.5 miles down from the test site, demonstrating the feasibility of using compressor stations so remote that they approach the electrical transmission line in distance spanned between power applied and power derived.

JOBS FOR GRADUATES

SKIES have brightened considerably for engineering-college graduates during the past two years. Instead of wondering about the chances of securing jobs, whether they be in their own line or any line at all, they are discovering that industrial concerns are looking them up ahead of graduation and speaking for their services. Some of the better students are even having to make a choice between several offers. Technical colleges are, of course, the reservoir from which is drawn that vital ingredient, brains, without which no company can long endure. A wise industrialist said when the depression came on that the shutting down of factories didn't worry him, but that the necessity of letting trained men go did. "I can easily build new factories or buy new machinery," he commented, "but it takes years to form an efficient human organization."

Manufacturers, consequently, are as pleased as the young graduates that the upswing in business permits them once more to add college men to their staffs, for they realize that this injection of new blood is the finest tonic for concerns that dare not become smug or complacent if they hope to continue as leaders in their lines. In these students they find optimism, fresh viewpoints, and lack of fear of any problem or any threatening black clouds. They are daring and willing to break tradition. Teamed with older, more experienced, more conservative men to guide them, their energy and resourcefulness push things through. They are like new coal to an ebbing fire.

The new crop of college men is amazingly capable, and this is attributed to the fact that the scarcity of jobs has caused some of them to do post-graduate work. Some of them have gone to two or more schools, picking their subjects with keen understanding and applying themselves diligently to the task of getting all that they could from classrooms, laboratories, and libraries. It is beginning to be evident that youth has done a lot of straight thinking during the business drought. Fortunately this seriousness about education has not made these boys too staid. They still have a sense of humor and still are of the opinion that life owes them a good time. But they are willing to work for it. All in all, the future of American manufacturing appears to be in good hands.

MEASURING NOISE

HOW loud is a watch tick? The average person would have difficulty in answering this question, because there is no commonly accepted scale of sound measurement. We have units for measuring distances, areas, volumes, and weights. All of us know the terms generally used in connection with them and we can, accordingly, understand exactly what is meant when someone says something is 4 feet long, 2 feet high, and weighs 44 pounds. When it comes to sounds, however, we are limited to such indefinite expressions as "quiet," or "loud," or "noisy," none of which is precise in its meaning. Another complicating circumstance is that human ears are not all attuned alike, and sounds of equal intensity do not register on all of them in the same manner.

Realizing that the first step in controlling noise is to devise ways of measuring it and terms of discussing it, the American Standards Association has had committees at work on the problem for several years. Their task is about finished. They have set a reference level for sound measurement that is akin to zero on the temperature scale or sea level on the altitude scale. They have adopted the decibel as the unit of sound measurement and have prevailed upon makers of sound meters to standardize their products so that a sound of given intensity will register the same on all meters. More than 150 terms used in the field of acoustics have been defined for the purpose of making it possible precisely to convey ideas. All this seems a bit strange now; but the day will come when people generally will be able to ascertain just how loud a sound is and to tell others in language that they will understand.

To get back to the question put at the outset, it may be surprising to many persons to learn that the intensity of the tick of one watch may be 100 times that of another. Considering that doctors until recently measured the keenness of hearing by means of a watch tick, it was time that something was done to secure a standard for acoustical use.

LOWER ELECTRICITY RATES

THE cost of electric current to the average family in 32 cities of the United States is 31 per cent less today than it was in 1913, notwithstanding the fact that the general cost of living has risen 40 per cent during the 23-year interval. The figures are from the Bureau of Labor Statistics. A kilowatt-hour, current sufficient to operate a 100-watt light for ten hours, sold for 8.1 cents in 1913. By 1930 it had dropped to 6.6 cents. Another cent was lopped off during the succeeding five years.

Primarily responsible for the decrease is the tremendous growth in power consumption. During the period under discussion the output of power plants rose 537 per cent. It is reasonable to assume that additional growth will bring further price reductions. This is the theory on which the Government is acting through its Rural Electrification Administration and its Electric Farm and Home Authority. The former is lending money for the extension of rural distribution lines: the latter is financing at low charges the purchase of electrical appliances in areas where rates for current are low. Coincidentally, electric lamps have been steadily cut in cost and improved in efficiency. The recent reduction in the case of the larger sizes of Mazda lamps was made possible primarily because the demand for them has greatly increased.

Lifter for Sheet Material

HANDLING piles of sheet material in course of manufacture can be greatly facilitated by the use of a patented lifter of simple design produced by the Industrial Products Company, Philadelphia, Pa. It consists essentially of a vacuum cup attached to a stout handle provided with a trigger that is easily manipulated with the thumb of the hand in which the tool is held. A smart blow of the suction cup on the surface of a blank will assure a firm grip, while pressure on the trigger serves to effect immediate release. Straight or curved sheets of metal, fiber, etc., can be handled with equal facility, and grease or oil on the surfaces increases the suction and therefore the lifting capacity. The Ipco Safety Vacuum Lifter, as it is called, obviates putting fingers and hands in presses in feeding them, and therefore safeguards them from injury.

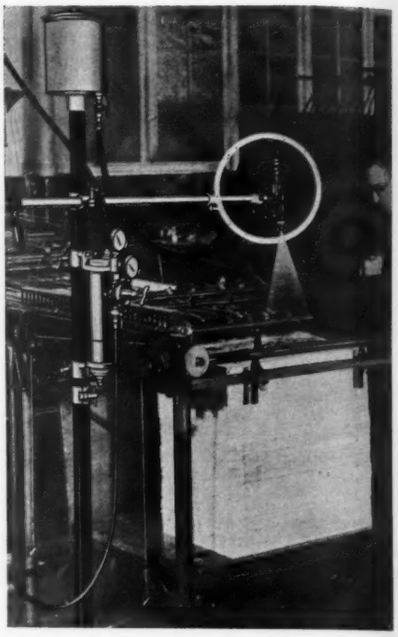
New Spray Prevents Offsetting in Printing

ONE of the bugbears in printing has been offsetting—the transfer of moist ink from each freshly printed sheet to the back of the next overlying one as they are stacked on coming from the press. In most establishments offsetting is combated by what is known as slip-sheeting. This consists of inserting a sheet of special absorbent paper between each pair of printed sheets to separate them. The operation must be done manually, and is both expensive and cumbersome because the slip sheets must subsequently be removed.

Several years ago a method was developed by which wax in a finely divided state is sprayed on each sheet, leaving a film which, although of microscopic thinness, parts the sheets sufficiently to prevent smudging. This system is used successfully in some large printing plants, but has necessarily required such extensive equipment as to place it beyond the reach of the average shop.

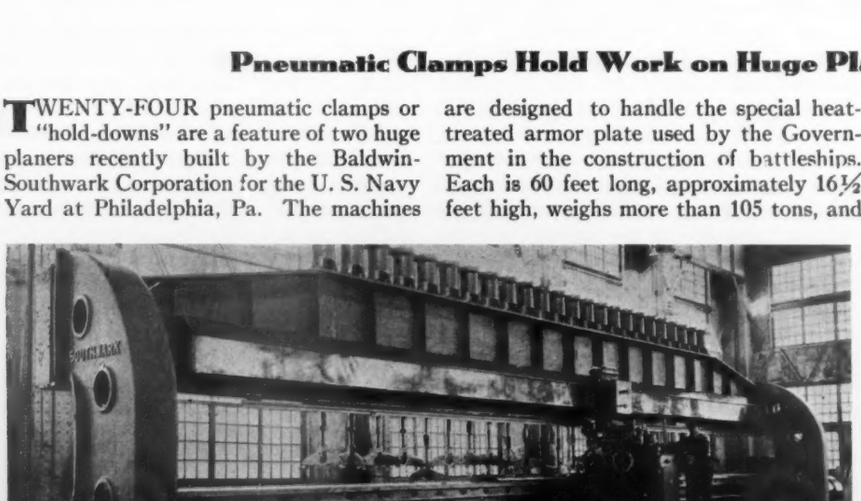
Now announcement has been made of a new apparatus that works on the same principle but which utilizes a different medium. Instead of wax it sprays a liquid which dries when atomized and falls upon the sheet in powder form. It is claimed to be nongummy, and to be invisible to the eye even when used as many as four times on the same sheet when printing five superimposed colors.

Spraying is effected with compressed air, and a special gun has been designed for the purpose by the Binks Manufacturing Company, of Chicago, which also makes the rest of the unit. A small compressor is included in the outfit when compressed air is not available in the purchaser's plant. The apparatus is marketed by one of the larger suppliers of printing equipment.



Pneumatic Clamps Hold Work on Huge Planing Machine

TWENTY-FOUR pneumatic clamps or "hold-downs" are a feature of two huge planers recently built by the Baldwin-Southwark Corporation for the U. S. Navy Yard at Philadelphia, Pa. The machines are designed to handle the special heat-treated armor plate used by the Government in the construction of battleships. Each is 60 feet long, approximately 16½ feet high, weighs more than 105 tons, and is operated by a 50-hp. motor. To support so great a mass it was necessary to provide a firm foundation consisting of 30 piles, driven into the ground to a depth of 60 feet, and of a superimposed block of concrete 5 feet thick in which the machine is anchored.



WORKS AUTOMATICALLY

One of the two great metal-plate planers prior to its installation at the Philadelphia Navy Yard. Ranged along the top of the machine are air cylinders that actuate a corresponding number of clamps shown in various positions immediately above the working table. These clamps can be operated independently, the number used depending upon the length of the plate in process of machining. The planers are said to be the first of their kind to be equipped with electrically fed cutting tools.

Plates ranging in length from 6 to 36 feet and up to 5 inches in thickness can be cut, scarfed, or beveled. They are hoisted on to the working table and locked in position by the clamps which, with air at 100 pounds, exert a combined pressure of 120 tons. The carriage travels back and forth automatically at a speed varying from 15 to 45 feet per minute, and each time it is reversed at the end of the stroke the 1½-inch hard-steel cutting tools are also automatically adjusted by an electric feeder that is set at the beginning of operations. The maximum vertical adjustment of the tools is 11½ inches and the maximum horizontal adjustment 19 inches. In planing, the depth of cut made ranges from one-hundredth to one-quarter inch and the width up to one inch, while keyways or interlocking joints in deck plates, etc., are cut to depths varying from ¾ inch to 1½ inches. Despite the ponderous size of the machine, the work done is accurate within one-thousandth of an inch.

Industrial Notes

It has been suggested that catapults could be used to advantage at airports for the launching of airplanes. In that case compressed air would serve to give them their flying start.

An innovation in electric fans has appeared on the market. Its blades are molded of rubber and are sufficiently tough and flexible to deliver continuously a strong current of air without injury even to a child's inquisitive finger.

A new detinning process that makes use of acetic acid instead of the usual chloride is reported from Great Britain. The treatment is said to be safer and simpler, and is effected in a chamber containing acetic-acid vapor. Reaction takes place at ordinary temperatures, but can be expedited by heating.

An improved type of splint has been developed that will enable industrial first-aid workers to take care of broken legs easily and effectively. It is known as the Greene Traction Splint, and is distributed by the Davis Emergency Equipment Company, Inc., 55 Van Dam Street, New York, N. Y.

Basalite is a new building block that is made of cement and pumice and can be sawed and nailed. The material is claimed to be light, to have a structural strength of 1,600 pounds per square inch, to possess a high degree of insulation against heat and cold, and to be a good base for plaster and stucco. It is manufactured in a plant equipped for a daily capacity of 10,000 blocks.

Plating solutions can be kept free of sludge by putting the anode in a bag before suspending it in the bath. Containers for this purpose are available, and consist of two cloth bags one inside the other with a layer of filter paper in between. Each time a new anode is required it is put in a new container, the old one being discarded with the sludge. It is said that the efficiency of plating solutions can thus be maintained and that rough and pitted work is prevented.

Mines with far-reaching underground workings are making their compressed-air supply systems serve as fire-alarm systems as well by introducing into the lines a liquid with a strong odor that is noticeable the instant air escapes at the points of use. The method of application is generally the same, but the fluid employed may vary. In the case of a well-known Canadian mine, ethyl mercaptan is kept ready in the compressor house for immediate release into the two air lines that serve the workings. The liquid is sealed in what are called stench bombs—the odor of ethyl mercaptan being suggestive of garlic. A South African mine, on the other hand, introduces eucalyptus oil which is less offensive to the olfactory organ, highly penetrating and volatile, and can be relied upon quickly to carry its warning message even beyond the points where compressed air is fed to drills, etc.

Ingersoll-Rand Company has recently announced a "Stopehamer" of new design, one that makes use of an entirely new method of drill-steel rotation. The customary pawls, pawl springs, and ratchets are lacking: instead, a reciprocating movement is imparted to the rifle bar by a piston in conjunction with air pressure applied alternately to the faces of the rifle-bar head. With the forward stroke of the piston the teeth of the rifle bar are disengaged, permitting the bar to rotate freely. With the return stroke the teeth are again engaged but in an advanced position, and helical

flutes in the locked rifle bar rotate the piston which, in turn, causes the steel to rotate. The teeth can be kept disengaged if hammer action without rotation is desired for collaring a hole. This is effected by simply turning a quick-acting throttle valve, another feature of the tool made possible by the new method of rotation. The "Stopehamer" comes in two sizes—the SAR 120 and the SAR 85, and each is claimed to be the fastest tool in its weight class. For a detailed description of them write to the company, 11 Broadway, New York, N. Y., for Bulletin No. 2245.

To prevent overloading a long conveyor that delivers gravel to a washing and screening plant, the washer is equipped with a relief mechanism that automatically checks the flow as soon as it exceeds the quantity that can be handled safely. By this arrangement an air valve is opened at times of overload and compressed air is admitted into a cylinder, causing the piston to disengage the conveyor clutch. When the feed is once more normal, the air valve is automatically closed, and springs force the piston back to the starting point where it serves to reëngage the clutch, the air the while escaping through a small hole in the cylinder head.

How to Belt Your Drives for More Profit is the title of a 39-page handbook recently published by E. F. Houghton & Company, 240 W. Somerset Street, Philadelphia, Pa., for the purpose of giving to leather-belt users in convenient form the information they need to assure efficient power transmission. It is profusely illustrated and contains a number of chapters dealing with such subjects as Vim leather, Vim Tred leather belting, Vim efficiency drives, special belts for special purposes, and helpful facts for the belt man, concluding with transmission data, engineering tables, formulae, and a list of "don'ts." Representing, as the reference book does, the cumulative experience of 40 years of power-transmission problems, it should prove both helpful and instructive to anyone having to do with belt drive. A copy may be obtained from the aforementioned company upon request.

An important development in the marble industry has been announced by the Vermont Marble Company which, in coöperation with the Mellon Institute, has produced a translucent marble that has been given the trade name of Lumar. After three years of research they have succeeded through scientific selection and processing in giving the natural stone a high degree of luminosity and in bringing out its subsurface coloring and texture—effects impossible of attainment in the past with such artificial means as staining, waxing, or polishing. Markings and coloring that have heretofore remained hidden in the stone are revealed in all their beauty and, when illuminated from behind, are greatly intensified. This power to transmit light will give marble, which has always been in favor with architects for interior and exterior decorative purposes, a new field of usefulness—the lighting industry.

Intake Filter

During the recent dust storms West of the Mississippi, as much as 30 tons of dust per square mile were deposited in some sections. Some of the fine sand and silt was carried 200 miles.

The U. S. Weather Bureau estimated that 5,000 tons of dust were constantly floating over Washington during a dust storm in 1934—enough to load a string of one-ton carts 25 miles long.

Dust can safely be considered Public Enemy No. 1 to compressors, Diesel engines and pneumatic tools. For the sharp abrasive particles in dust quickly wear cylinders, pistons, bearings, valves and other moving parts, cause carbon and make valves stick.

Protect your air-using equipment with Protectomotor Intake and Pipe Line Air Filters. They frequently save enough money in repairs to pay for themselves in one month.

Protectomotor Filters prevent 99-9/10% of the dust particles in the air from getting into machines and tools. Therefore wear is reduced 75 to 85% and machines kept running 3 to 5 times longer before overhauling is needed. About ¾ of the work and expense of cleaning carbon and grinding valves is eliminated. Oil consumption is cut 25% and compressed air saved.

Protectomotor Air Filters pass air through a dry filter medium of negligible resistance. Its efficiency is not reduced by collected dust. They operate from 6 months to a year without cleaning and can be cleaned quickly with compressed air without removing the filtering unit. They have no moving parts and require no cleaning tanks or adhesives.

To prove the big savings effected by Protectomotor Air Filters we'll send one free for 30 days trial. No proof, no charge. Thousands have been sold on that test alone.

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